# BASIC WATER TREATMENT OPERATION

1974





Ministry of the Environment
Ontario

The Honourable William G. Newman, Minister

Everett Biggs, Deputy Minister

# BASIC WATER TREATMENT
# OPERATION

*Training & Certification Section*
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*Activated Sludge Process Analyses and Interpretation Workshop*

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## BEHAVIORAL OBJECTIVE APPROACH TO TRAINING (*BOAT*)

The behavioral (performance) objectives are designed to tell the operator, or trainee, what he will have to know and do in order to complete the course successfully. At the same time, it tells the instructor what he *must* teach, describe, or demonstrate so that the trainee will reach his goal--not what he would *like* to teach.

### WHAT IS BOAT?

BOAT is a method of training which states briefly and clearly what the performance of a trainee should be upon completion of a learning period. The objectives are set down at the beginning of each topic so that both the trainee and instructor know what must be done. To verify successful completion, tests are given under conditions as similar as possible to actual on-the-job working conditions. If the test requires an actual "hands-on" performance, the trainee will be tested accordingly.

Objectives serve other purposes as well: they enable the operator to determine how well he is doing on a particular topic, and they also enable the instructor to organize his time for maximum efficiency.

### LEVEL OF COMPETENCE

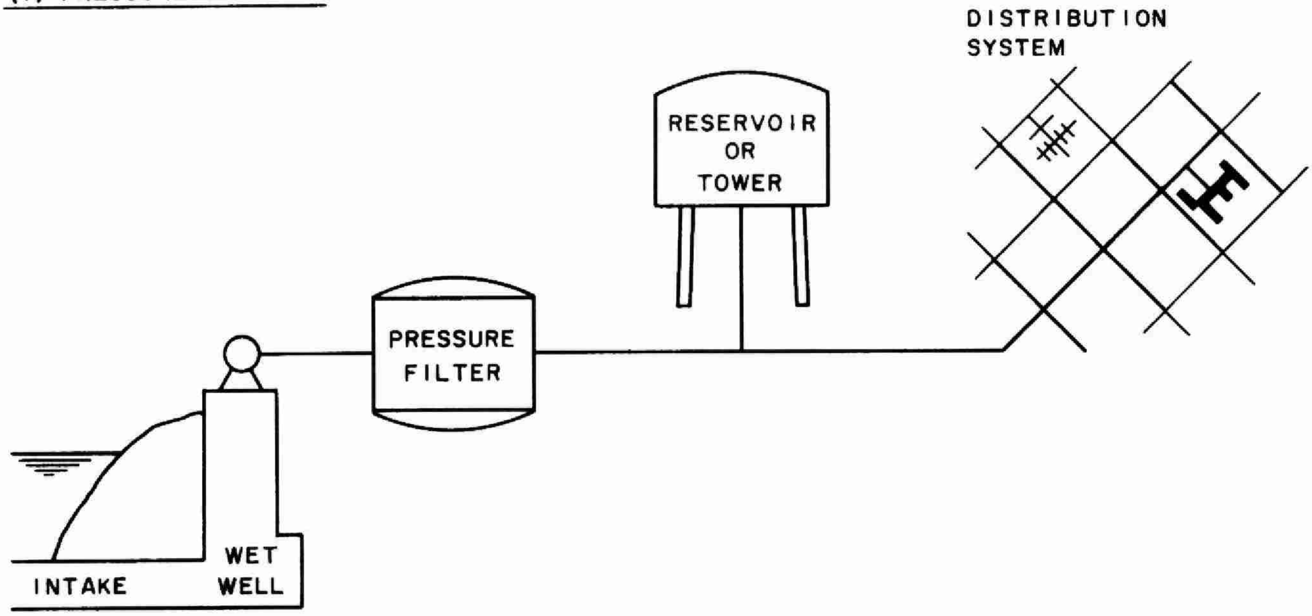
Each topic has stated objectives which must be presented to the trainee at the course. To fulfill the Basic Water Treatment Operation course requirements, the trainee must achieve a minimum average of 70% on all topics (written, oral, and hands-on testing).

# TABLE OF CONTENTS

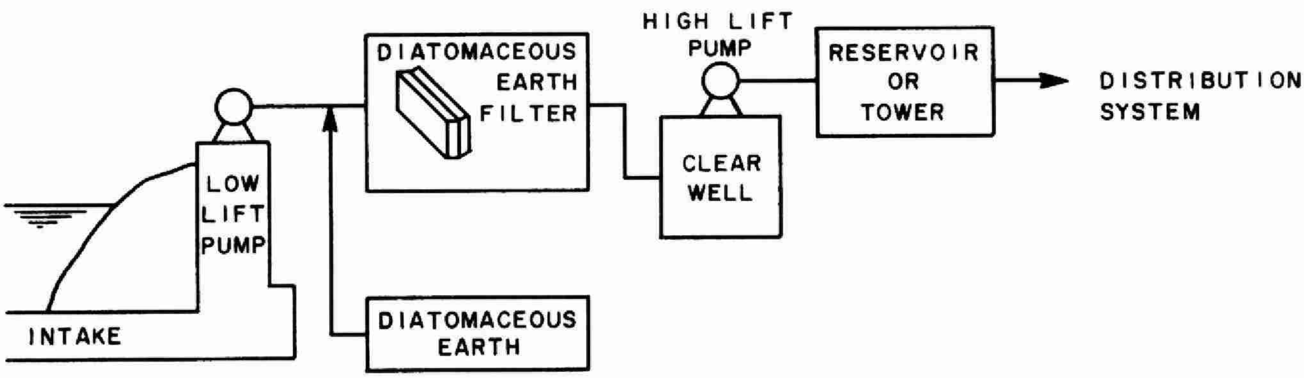
# SURFACE WATER TREATMENT SYSTEMS COMMON IN ONTARIO

## LOW RAW WATER TURBIDITY

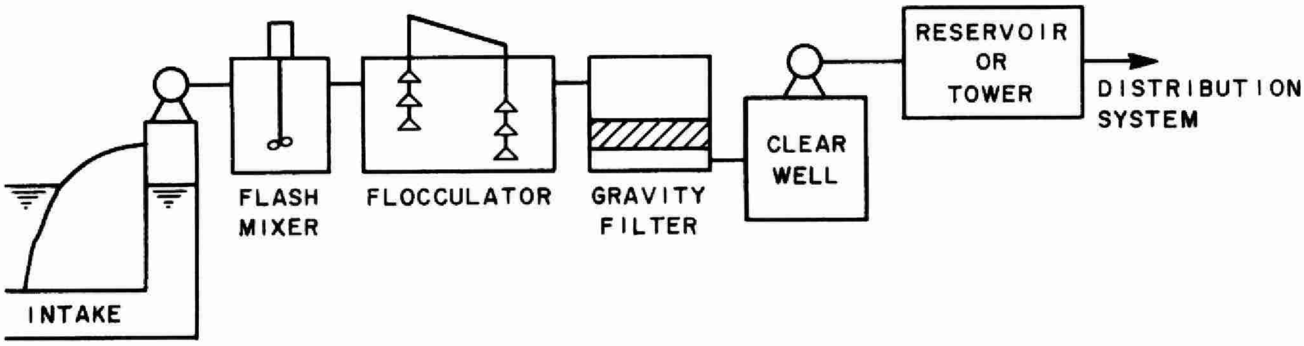
### (1) PRESSURE FILTERS




### (2) DIATOMACEOUS EARTH FILTRATION



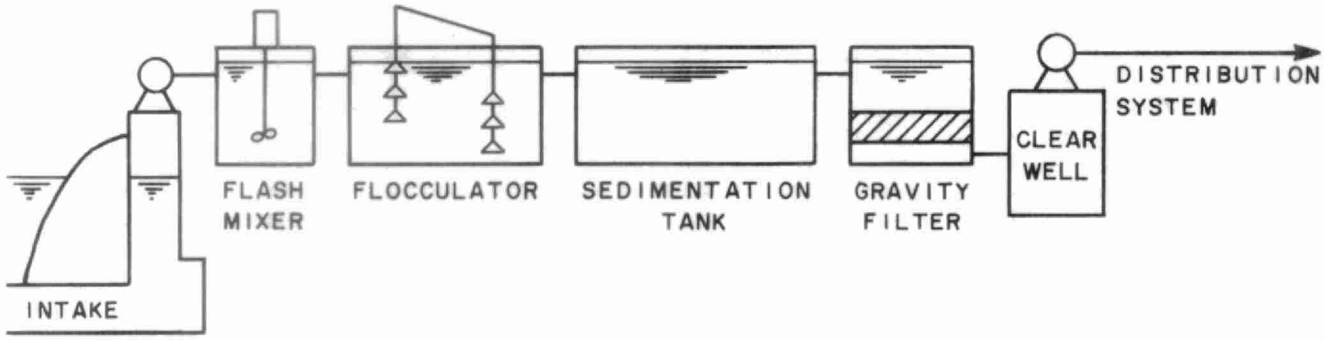

### (3) DIRECT FILTRATION



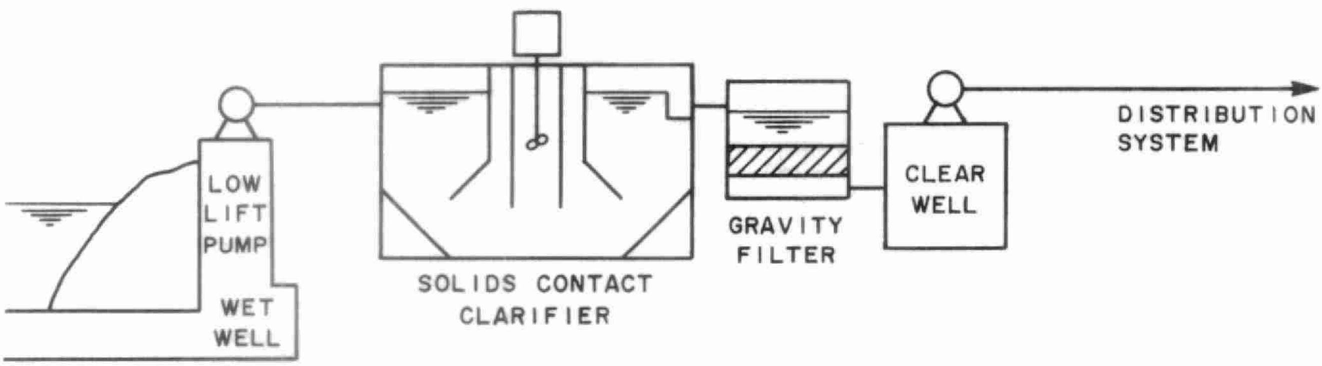
## SURFACE WATER TREATMENT SYSTEMS COMMON IN ONTARIO

HIGH RAW WATER TURBIDITY

(1) SEDIMENTATION

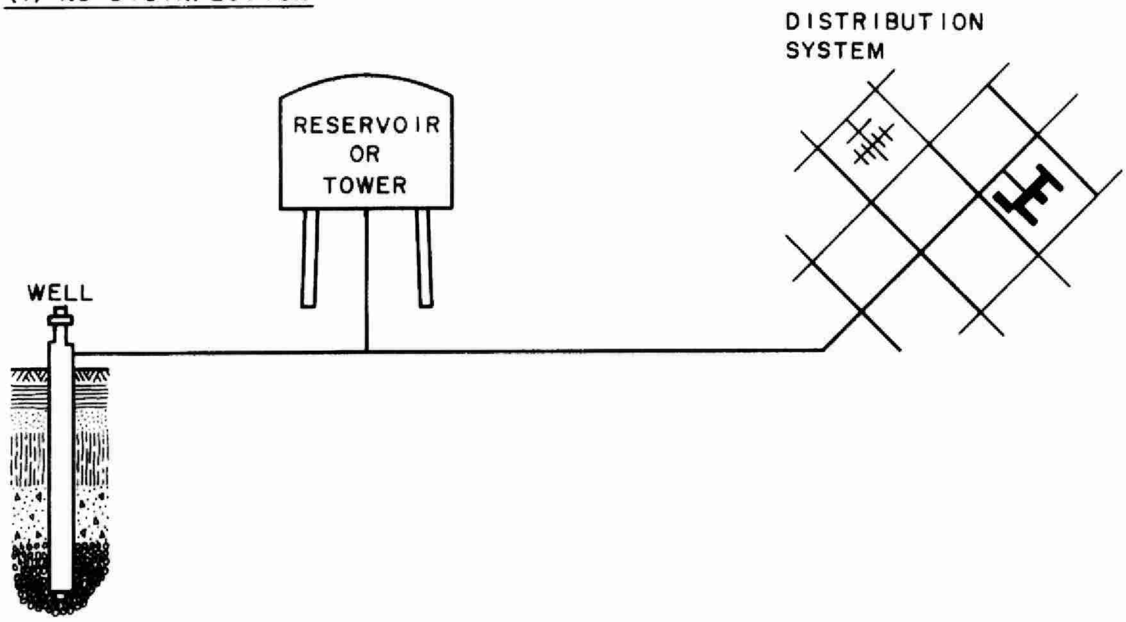



(2) CLARIFICATION

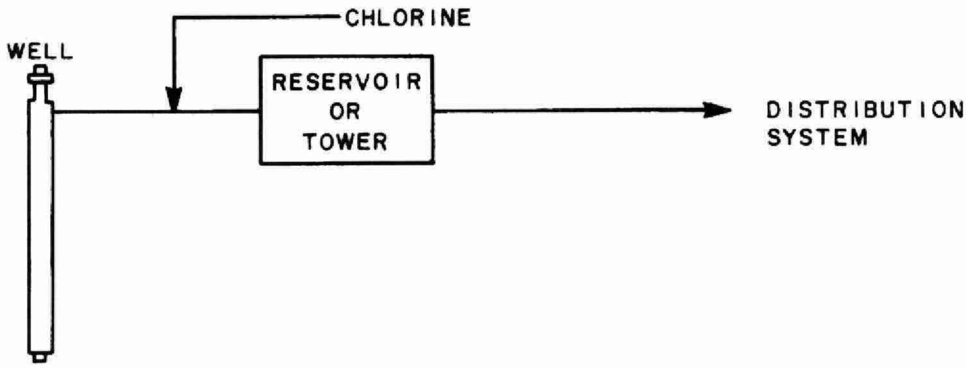


# GROUND WATER TREATMENT SYSTEMS COMMON IN ONTARIO

(1) NO DISINFECTION




(2) CHLORINATION

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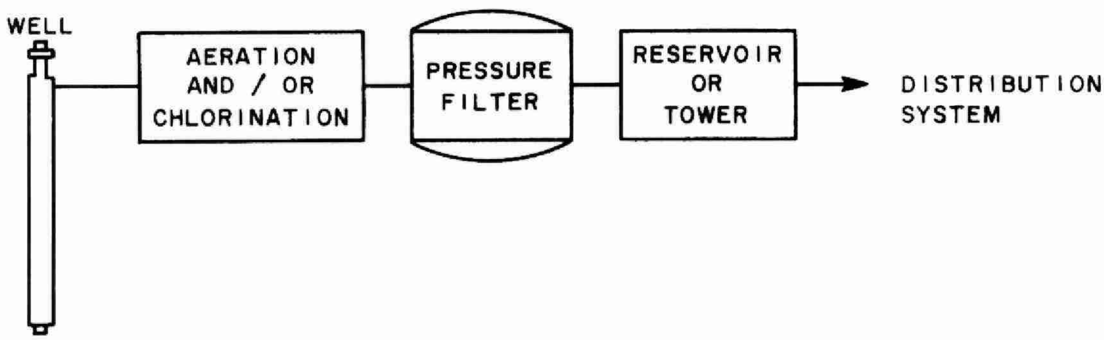


SUBJECT:

BASIC WATER TREATMENT OPERATION

TOPIC: 1

WATER QUALITY OBJECTIVES AND PUBLIC HEALTH SIGNIFICANCE

OBJECTIVES:

Trainee will be able to:

1. Name 2 techniques for lab examination of samples to determine bacteriological quality;

2. Determine the minimum number of samples required from the SOURCE and their frequency;

3. Determine the minimum number of samples required from a DISTRIBUTION SYSTEM and their frequency;

4. Identify and describe the physical characteristics of water which water works operators must recognize;

5. Identify and describe the problems associated with various chemical substances in water;

6. Describe the following characteristics of water:
   (a) acidity, (b) alkalinity,
   (c) hardness,
   (d) hydrogen sulphide.

## WATER QUALITY OBJECTIVES AND PUBLIC HEALTH SIGNIFICANCE

### GENERAL

While some analytical results have more importance than others, all have certain limiting values established to protect the health of the individual and the well-being of the community. These limiting values, or "Water Quality Objectives", will be discussed with a view to their role in attaining the above goals. These objectives were formally adopted by the former OWRC in 1964 and updated by amendment in 1967. The discussion will be divided into three sections: *bacteriological, physical* and *chemical* characteristics.

At the present time, there are approximately 438 municipal water works systems in the Province of Ontario. These systems have a total capacity of 1.712 billion gallons per day and serve 6 million people. Since the total estimated potential population that could be served by the systems is 6.2 million the present systems are serving 97% of the possible consumers. In a Province having a population of 7.4 million, it is therefore concluded that the present systems are serving 81% of the total population.

These basic statistics on the extent of municipal water supplies in Ontario illustrate the importance of providing safe potable water to the consumers at all times.

### IMPORTANCE OF AN ADEQUATE BACTERIOLOGICAL SAMPLING PROGRAM

Communities have been relatively free of attack for generations but the possibility of a water-borne epidemic still exists. Periodically over the past few years, epidemics related to contaminated water supplies have been reported. For example, in *November* and *December* of *1959*, the community of Keene, New Hampshire, experienced a typhoid epidemic. The source of the infection was finally traced, after considerable investigation, to the Keene water supply. This community's water supply consisted of an unspoiled mountain watershed and a good, slow sand filter treatment plant. All of these

factors, combined with careful water distribution practices, would indicate that the consumer was receiving a safe quality water. Yet overnight the water system turned into a distributor of the organisms of deadly typhoid fever.

A curious combination of circumstances led to the typhoid infection. A wood cutter, working in the watershed area without authorization, was discovered to be a typhoid carrier. His waste had been washed into the city's water during unusual flooding in *October*.

The epidemic at its height affected 19 people and was known to have taken the life of one person. The city officials were suddenly made aware that the city was in the business of producing a product -- and they had a legal and moral responsibility to guarantee its safety. The Council was faced with the alternatives either of paying $67,000 in settlement of claims or allowing these claimants to sue the city. One attorney estimated that the costs of going to court could have risen as high as one-half million dollars ($500,000).

For at least a decade prior to the epidemic local health and water authorities, the city's consulting engineer, and the State Board of Health, had all recommended the installation and continuous operation of chlorination facilities. The City Council repeatedly denied the requests. The result: Keene paid several times the cost of the installation and operation of chlorination facilities, and derived no benefits from it. Further, the Water Department suffered a considerable loss of face.

This example points out that there will always be a need for continued responsible supervision at any water treatment plant to ensure that the quality of the water will not be affected and that there will be no return to the water-borne epidemics of another era. The first public health requirement in water works treatment is responsible supervision to assure proper standards in maintaining water quality.

## THE IMPORTANCE OF KNOWING YOUR WATER SUPPLY

The job of keeping our drinking water safe has become a vital and increasingly difficult task. The war against pollution is only beginning. Municipalities still discharge untreated or partially untreated sewage into the streams, and industry aggravates the problem by dumping an ever-changing variety of chemical contaminants.

The water works, and particularly those in the larger and more populated areas, are now confronted with problems that did not exist until a few years ago. If the water treatment works are to function properly, it is essential that their personnel know the sources of contamination that are or may become a danger to the quality of the water in their plant. The amount of close supervision required in operating a plant is materially increased in those areas where known sources of contamination are present.

Sources of industrial waste pollution as well as upstream sewage treatment plants should be known to the personnel of water works plants. An ever-changing variety of chemical and other waste discharges are reaching water works plants. As a result, most water works in industrial areas have some type of waste control treatment available. Radiological, anionic detergent, pesticide, phenolic and other organic wastes from industrial sources and from land run-off have brought new problems that are often difficult to solve. Industries are sometimes located extremely close to water works intakes, increasing the need for careful supervision in the water works plant.

## BACTERIOLOGICAL CHARACTERISTICS

### MPN AND MF TECHNIQUES

There are three methods or techniques in general use in this province for the laboratory examination of samples to determine bacteriological quality; the *Most Probable Number (MPN)* technique, used by the Ministry of Health, the *Membrane Filter Technique (MF)*, and the *Presence/Absence Test (P/A)*. The latter two are used by the Ministry of the Environment.

For all practical purposes, the results from the MPN and MF tests are comparable. There is, however, a slight difference in the interpretation of the significance of actual numbers of coliforms indicated in each 100 millilitre (ml) portion. None of the samples having coliform organisms should have an MPN index higher than ten per 100 ml. In the MF technique none of the coliform counts should be higher than four per 100 ml.

## Presence-Absence Test

A third method of analysis involves running a series of Presence-Absence tests to confirm the *presence* or *absence* of a variety of pollution indicator bacteria. This method is presently being used on nearly all municipal water samples submitted to the Ministry Laboratory. The test offers a distinct advantage over others since the results are known within 18-24 hours. If there is a presence of bacteria, other tests are conducted to determine the types. The test on treated water or distribution samples should be *absent* of bacteria.

## Sampling: Why?

If water samples approach or go beyond the limits in consecutive examinations, an immediate investigation should be made to eliminate it. At the same time a series of special samples are required to determine the extent of contamination and the progress being made towards its elimination from the water supply. This special sampling is continued until the bacteriological water quality is again satisfactory. *Special samples are also required when more than 10 per cent of the samples collected per month show the presence of coliform organisms.*

## Frequency of Sampling

Contamination is often intermittent and may not be revealed by analysing a single sample. A single sample shows only the conditions at the time of sampling; a satisfactory

result does not guarantee that conditions will remain the same. Therefore, a series of samples taken regularly over a period of time is required.

To ensure reliable results, samples should arrive at the testing laboratory *within 24 hours of sampling* or be refrigerated if delay is unavoidable. The sample should be collected *directly* into sterile bottles -- do not use a dipper or other container. *Reliable results depend on using proper sampling techniques and the necessary care when collecting the samples.*

The minimum number of samples required from the *SOURCE* is shown in the following table:

| Description of Source | No. of Samples | Minimum Frequency of Sampling |
|---|---|---|
| Treated Surface Water | 1 raw and 1 treated at plant | once per week |
| Treated Ground Water | 1 raw and 1 treated from each source | twice per month |
| Untreated Ground Water | 1 raw from each source and 1 from each point of entry into the distribution system | once per week |

The minimum number of samples to be collected and the frequency of sample collection from a *DISTRIBUTION SYSTEM* shall be determined from the following table:

| Population Served | Number of Samples per Month | Minimum Frequency of Sampling Intervals |
|---|---|---|
| up to 1,000 | 2 | twice per month |
| 2,000 - 10,000 | 2 + 1 per 1,000 of population per month | once per week |
| 1,001 - 100,000 | 10 + 1 per 1,000 of population per month | once per week |
| 10,001 - 100,000 | 10 + 1 per 1,000 of population per month | once per week |
| over 100,000 | 100 + 1 per 10,000 of population per month | once per day |

The number of samples determined with the use of the above table shall not include plant effluents whether treated or otherwise.

Example

A municipality of 2,400 persons with two wells provides treated ground water to the system. Bacteriological sampling consists of the submission of a raw water sample twice a month from each of the sources of supply and a treated water sample from each point of discharge to the distribution system. Also, four bacteriological samples a month must be taken from various points in the distribution system. This involves one sample a week to meet the sampling frequency requirement.

*The responsibility for taking the required number of samples lies with the operating authority, whether it be a municipality or an individual who owns a private water supply.* The total number of samples collected monthly may consist of those examined by the Ministry, other government laboratories, water works authorities or even by commercial laboratories, if the analytical results are acceptable to the Ministry. Special samples shall not be included in the total number of samples required above.

PHYSICAL CHARACTERISTICS

Physical tests do not measure the safety of a water supply, but they do give an indication of its acceptability to the consumer. This is why the objectives adopted by the Ministry to govern the physical characteristics of the water are not as strict as those required for bacteriological control. The physical qualities which concern water works operators are: a) *turbidity*, b) *colour*, c) *taste and odour*. (These results are not reported in milligrams per litre). Another physical characteristic measured but uncontrollable is d) *temperature*.

a) Turbidity

Turbidity should average not more than 1 unit. At levels approaching 10 units, the water appears cloudy. Plants with complete treatment should routinely produce water which meets this objective. Ground water supplies will normally

meet the objective without the need for treatment.

(b) Colour

Colour should average not more than 5 (apparent colour) units. Colour does not occur too frequently in the natural waters of southern Ontario. However, due to the leaching effect of the water on organic material found in the watersheds of northern Ontario, waters in this region may range beyond 50 units. Colour removal is possible using alum coagulation, sedimentation and filtration.

(c) Taste and Odour

The Ministry objective for odour is a threshold odour number not greater than 3 and the taste should not be objectionable. Taste and odour are very closely related and are caused by the same conditions. Common sources of taste and odour are:

1. dead or decaying organic matter
2. living organisms and oils from algae
3. industrial wastes (phenolic wastes may produce a medicinal taste and odour at concentrations as low as 1 part per billion (ppb) when contacted by chlorine)
4. dissolved gases (hydrogen sulphide, methane,etc.)
5. dissolved minerals (chlorides, sulphates and metallic salts such as copper and iron)

*Physical characteristics provide only part of the picture of water quality.* They are, however, very important when related to surface waters which are of variable quality. Normally ground water will meet the necessary physical requirements, but occasionally taste and odour in a well or spring supply will be significant. Any amount of hydrogen sulphide gas in a well supply will usually discourage use of the well.

Turbidity, colour and taste and odour requirements can be attained by properly designed and operated treatment plants and distribution systems. Failure to meet the requirements indicates either inadequate treatment facilities or improper operation of the system.

Consumers will not accept water sources which do not meet these basic objectives. They will seek and use an alternate source if it is available. Therefore, these characteristics indicate whether or not consumers will accept the product which is being marketed.

(d) Temperature

Very little can be done about water temperature. The most desirable range is from $40^{O}F$ to $50^{O}F$. Higher temperatures make water less palatable and reduces its suitability for air conditioning purposes. Temperatures above $80^{O}F$ are unsuitable and above $90^{O}F$ render the water unfit for public use.

## CHEMICAL CHARACTERISTICS

Normally, analyses for chemical constituents are only needed twice a year. But if the supply is suspected of containing undesirable materials, periodic determinations for the suspected toxicant or material should be carried out more frequently (every month for example). On the other hand, where experience, examination and results indicate that particular substances are consistently absent from a water supply or are below levels of concern, then, with the approval of the Ministry, semi-annual examinations *for these substances* may be omitted.

### Limits for Chemical Constituents

The chemical constituent concentrations in water may be broken down into two categories; (a) those concentrations which can be tolerated if a better source is not available;

(b) and those concentrations which constitute grounds for rejection of a supply. Because of the rapidly changing field of complex chemicals it has become important that the objectives for chemical constituents be reviewed regularly.

The chemical substances shown in the following table should *NOT* be present in a water supply in excess of the listed concentrations where, in the judgment of the Ministry, other more suitable supplies are or can be made available.

| Substance | Concentration mg/l or ppm |
|---|---|
| Alkyl benzene sulphonate (ABS) | 0.5 |
| Arsenic (As) | 0.01 |
| Chloride (Cl) | 250.0 |
| Carbon chloroform extract (CCE) | 0.2 |
| Cyanide (CN) | 0.01 |
| Fluoride (F) | 2.4 |
| Iron (Fe) | 0.3 |
| Manganese (Mn) | 0.05 |
| Nitrate ($NO_3$) | 45.0 |
| Phenols | 0.001 |
| Sulphate ($SO_4$) | 250.00 |
| Total Dissolved Solids | 500.0 |
| Zinc (Zn) | 5.0 |

The presence of substances in excess of the concentrations listed below shall constitute grounds for rejection of the supply.

| Substance | Concentration mg/l or ppm |
|---|---|
| Arsenic (As) | 0.05 |
| Barium (Ba) | 1.0 |
| Cadmium (Cd) | 0.01 |
| Chromium ($Cr^{+6}$) | 0.05 |
| Cyanide (CN) | 0.2 |
| Fluoride (F) | $>$ 2.4 |
| Lead (Pb) | 0.05 |
| Selenium (Se) | 0.01 |
| Silver (Ag) | 0.05 |

## Problems Associated with Chemical Constituents

The chemicals that occur most frequently and create significant problems in the distribution system as well as for the consumer are discussed first.

### Iron (Fe)

An upper limit of 0.3 mg/l for iron has been adopted as an objective.

Iron in water can be highly objectionable for either domestic or industrial supplies. The domestic consumer complains that iron imparts a brownish colour to plumbing fixtures and laundered goods. In addition, iron appreciably affects the taste of beverages.

Added problems often develop in the distribution system as a result of the growth of iron bacteria, which thrive in the presence of iron. These bacteria present staining problems by converting iron in solution into red, insoluble matter. Watermains may become fouled by the masses of stringy growths associated with iron bacteria.

Iron may be removed by ion exchange, aeration, settling and filtration and iron bacteria may be controlled by chlorination.

### Manganese (Mn)

Manganese presents much the same nuisance conditions as iron. It is difficult to remove this chemical and it is recommended that concentrations not exceed 0.05 mg/l.

### Nitrate ($NO_3$)

This Ministry has adopted the objective of 45.0 mg/l of nitrate ($NO_3$). In areas where the nitrate content

of water is known to be in excess of the listed concentration, the public should be warned of the potential dangers of using the water for infant feeding.

Serious and occasionally fatal poisonings of infants have occurred following ingestion of well waters containing high levels of nitrate. Wastes from chemical fertilizer plants and field fertilization may be sources of such pollution.

Nitrate poisoning seems confined to infants during their first few months of life. The nitrates give rise to infantile methemoglobinemia ("blue-baby" condition). It can be cured or terminated by providing nitrate-free water.

Sulphate ($SO_4$)
A recommended upper limit of 250 mg/l has been adopted.

Sulphur has a laxative effect on newcomers and casual users of waters high in sulphates. A person does however, become accustomed to the use of these waters in a relatively short time. The taste of the water may also be adversely affected.

Chloride (Cl)
The objective for chloride has been set at an upper limit of 250 mg/l. Above this level a salty taste is apparent. Many municipalities experience higher levels of chloride with varying taste intensities. Abnormal amounts of chloride in a natural water suggests pollution probably of a chemical origin.

Although the presence of any of the following chemicals in a water source would be quite significant their

rate of occurrence is quite low. They are listed alphabetically:

Alkyl Benzene Sulphonate (ABS)
The objective for ABS in water supplies has been set at 0.5 mg/l. Tests have confirmed that 1 mg/l presents an off-taste to water and at this level foaming often occurs. No apparent toxic effects were evident when tests were conducted with water containing 50 mg/l of ABS. ABS will contaminate drinking-water supplies by its disposal, as household and industrial wastes, into sources of raw water. The concentration of ABS in municipal sewage ranges as high as 10 mg/l. Such contamination may appear in both surface and ground water supplies.

Arsenic (As)
The present knowledge concerning the potential health hazards associated with the ingestion of organic arsenic indicates that the concentration of arsenic in drinking water should not exceed 0.01 mg/l and concentrations in excess of 0.05 mg/l are grounds for rejection of the supply.

The widespread use of inorganic arsenic in insecticides and its presence in animal foods, tobacco and other sources, make it necessary to set a limit on the concentration of this chemical in drinking water.

Barium (Ba)
This constituent is not particularly common but the Ministry has adopted the objective that concentrations in excess of 1.0 mg/l are grounds for rejection of the supply because of the serious toxic effects of barium on the heart, blood vessels and nerves.

Cadmium (Cd)
Tests have shown that concentrations up to 0.01 mg/l can be tolerated, but concentrations in excess of this are considered grounds for rejection of a supply.

Cadmium is recognized to be an element of high toxic potential. Very little attention has been paid to this constituent in the past.

Seepage of cadmium into ground water from electroplating plants has resulted in concentrations up to 3.2 mg/l. Other sources of cadmium contamination in water arise from zinc-galvanized iron in which cadmium is used.

Carbon Chloroform Extract (CCE)
The objective for CCE is 0.2 mg/l.

The Carbon Chloroform Extract (CCE) test is a practical measure of water quality and is a safeguard against the intrusion of excessive amounts of potentially toxic material into water. It is proposed as a technically practical procedure which will provide some protection against the presence of undetected toxic materials.

The test provides an indication of organic material in the treated water. The presence of organic material shows that pollutants have not been removed in the treatment process.

Chromium ($Cr^{+6}$)
Concentrations in excess of 0.05 mg/l as hexavalent chromium ($Cr^{+6}$) are grounds for rejection of the supply. Trivalent chromium is not believed to be of concern in drinking water supplies.

Chromium is another unnatural constituent of water supplies. It is not known to be either an essential or beneficial element in the body. Its presence indicates industrial pollution, probably caused by a plating or tannery operation.

Copper (Cu)

The concentration of 1.0 mg/l is the recommended objective.

Copper is an essential and beneficial element in human metabolism. It is well known that a deficiency in copper results in nutritional problems in infants. Copper imparts some taste to water and is detectable in ranges from 1 to 5 mg/l. Small amounts are *not* generally regarded as toxic; very large doses may cause sickness, and, in extreme cases may cause liver damage. When copper sulphate is used on a surface water supply for algal control, the levels of copper in the water must be closely controlled.

Copper in small amounts does not constitute a health hazard but imparts an undesirable taste to drinking water.

Cyanide (CN)

The Ministry objective is to reduce cyanide levels to less than 0.01 mg/l. For the protection of health, concentrations above 0.2 mg/l constitute grounds for rejection of the supply. The 0.01 mg/l concentration provides a necessary safety factor because of the rapidly fatal effect of cyanide.

Fluoride (F)

Where fluoride is added to the water supply, a 1.0 mg/l concentration is recommended. (A permissible operating range is 0.8 mg/l to 1.2 mg/l, as it is believed that mottling of the teeth occurs at and above this level.) Fluoride in drinking water

will prevent dental caries in children, and to a lesser degree, in young adults. When fluoride is naturally present, the concentration should not average more than 1.2 mg/l. Presence of fluoride in concentrations more than 2.4 mg/l shall constitute grounds for rejection of the supply.

Fluoridated and defluoridated supplies should be frequently sampled to determine that the desired fluoride concentration is being maintained.

Lead (Pb)

A concentration of lead in excess of 0.05 mg/l has been adopted as an upper limit for drinking water, and concentrations in excess of this amount are grounds for rejection of the supply.

Lead taken into the body can be seriously injurious to health, even lethal, if taken in by either brief or prolonged exposure.

Phenol

Undesirable tastes often result from the chlorination of waters containing extremely low concentrations of phenol. The objective for phenol has been adopted as 1 ppb (0.001 mg/l).

Selenium (Se)

Levels of selenium in excess of 0.01 mg/l constitute reasons for rejection of a water supply. While trace amounts of this chemical are considered to be essential to man, higher concentrations appear to be extremely toxic in a manner similar to arsenic. Surveys have shown that selenium may increase the rate of dental caries in permanent teeth.

### Silver (Ag)

A water supply shall be rejected if it contains more than 0.05 mg/l of silver. This level was established, not because of toxic effects, but due to the unsightly permanent blue-grey discolouration of the skin, eyes and mucous membranes which may result from its ingestion. Evidence indicates that silver, once absorbed, is held indefinitely in the tissues, particularly the skin.

### Total Dissolved Solids

High dissolved solids concentrations are associated with correspondingly high levels of sulphates and/or chlorides. An upper limit of 500 mg/l has been adopted as the objective, in order to exercise control over the taste and laxative properties.

### Zinc (Zn)

An objective of 5.0 mg/l has been adopted.

Zinc is an essential and beneficial element in human metabolism and does not appear to have a serious effect on health. The tendencies for zinc salts to impart a milky appearance to water at 30 mg/l and a metallic taste at about 40 mg/l are the only apparent undesirable characteristics.

## OTHER CHEMICAL CONSIDERATIONS

### Acidity and Alkalinity

Alkalinity and acidity of water refer to the amounts of acids or bases present and are measured in mg/l. These are not to be confused with pH which is measured on an arbitrary scale from 0 to 14 pH and is a measure of chemical activity or intensity. There are no particular limits for either alkalinity or acidity and both are expressed in terms of calcium carbonate ($CaCO_3$).

Acidity is characteristic of many northern waters; alkalinity is a characteristic of waters found in southern Ontario. Acidity is not desirable in a municipal water system, but it does not normally affect the potability or palatability of the water.

Alkalinity refers to the carbonate, bicarbonate and hydroxide content of a water. It usually occurs in the form of Calcium (Ca) and magnesium (Mg) bicarbonates.

Where the alkalinity *exceeds* the hardness (see below), basic salts, generally sodium (Na) and potassium (KO) are present.

If the alkalinity is less than the hardness, then salts of Ca and Mg are present in association with sulphates, chlorides or nitrates.

Hardness

The hardness content of Ontario water ranges from less than 10 mg/l to 1800 mg/l. A preferable hardness is in the range of 90 mg/l to 100 mg/l. Above 500 mg/l the water may be considered objectionable for domestic use. Waters with hardness less than 30 mg/l are quite soft and probably corrosive.

Carbon Dioxide ($CO_2$)

In surface supplies the normal carbon dioxide content will range from 0.5 to 2.0 mg/l while in ground water it will range as high as 50 mg/l. A proper balance of carbon dioxide in water will ensure that the water is neither corrosive nor scale-forming.

Hydrogen Sulphide ($H_2S$)

Even trace amounts of hydrogen sulphide will cause water to taste and smell like rotten eggs. It is not harmful from a health standpoint and may be removed by either chlorination or aeration followed by filtration.

pH

Natural waters generally range from 5.5 to 8.6 in pH value. Waters with lower pH tend to cause corrosion and in many cases an upward adjustment to the neutral range (pH 7.0) is necessary.

Phosphate (P)

In a natural, unpolluted water, phosphates present no problems. However, because of the increased use of detergents and commercial fertilizers, phosphates are being discharged into lakes and streams in high concentrations, greatly affecting biological activities in these waters. Consequently, they exert secondary effects on water supplies, often requiring additional treatment facilities. On the other hand, complex phosphates are often introduced into sources of supply for the prevention of corrosion and scaling in water distribution systems.

Radiological Limits

The exposure of humans to radiation is harmful, and any unnecessary exposures to ionizing radiation should be avoided. Concentrations which average above the values in the following table for a period of one year, shall constitute grounds for rejection of the supply.

| Radionuclides | Concentration u uc/l |
|---|---|
| Radium - 226 ($Ra^{226}$) | 3 |
| Strontium - 90 ($Sr^{90}$) | 10 |
| Gross beta activity ($Sr^{90}$ and alpha emitters absent*) | 1,000 |

* Absent is taken here to mean negligibly small fraction of the above specific limits, where the limit for unidentified alpha emitters is taken as the listed limit for $Ra^{226}$.

Where the total intake of $Ra^{226}$ and $Sr^{90}$ from all sources has been determined, the limits may be adjusted by the Ministry so that the total intake of $Ra^{226}$ and $Sr^{90}$ will not exceed 7.3 micro micro-curies (u uc) per day and 73 u uc/day, respectively. When mixtures of $Ra^{226}$ and $Sr^{90}$, and other radionuclides are present, the above limiting values shall be modified to ensure that the combined intake is not likely to result in exposure exceeding the Radiation Protection Guides recommended by the United States Federal Radiation Council.

SUBJECT:

BASIC WATER
TREATMENT OPERATION

TOPIC: 2

GROUND WATER SUPPLIES

OBJECTIVES:

Trainee will be able to:

1. Name 7 advantages of using ground water;
2. Name 3 disadvantages of using ground water;
3. Describe the water cycle;
4. Identify the hardness of water according to the hardness scale;
5. Identify the worst type of soil for ground water extraction;
6. Define the following terms: permeability, aquifer, artesian aquifer, recharge;
7. Determine the operating data required on a daily and weekly basis;
8. Give 3 reasons why artificial ground water recharge is practiced.

# GROUND WATER SUPPLIES

## WHAT IS GROUND WATER?

Water can be considered one of the most important natural resources of this country. Although we hear a great deal about the millions of lakes and streams in Canada, very little mention is made about waters hidden beneath the land's surface. This hidden wealth is called *ground water* and actually makes up the vast bulk of our fresh water supplies.

Although ground water makes up less than 1/3 of water *used* in Ontario, most estimates place the ground water supply in excess of 80%, and all surface supplies, including the Great Lakes, at less than 20%.

### Advantages to Using Ground Water:

(1) Can be developed on the site; transmission piping not necessary.

(2) Quality and temperature more constant.

(3) Savings on storage or reservoir space.

(4) Less easily polluted.

(5) Economical even in small developments.

(6) Often does not require treatment.

(7) More widespread than surface waters.

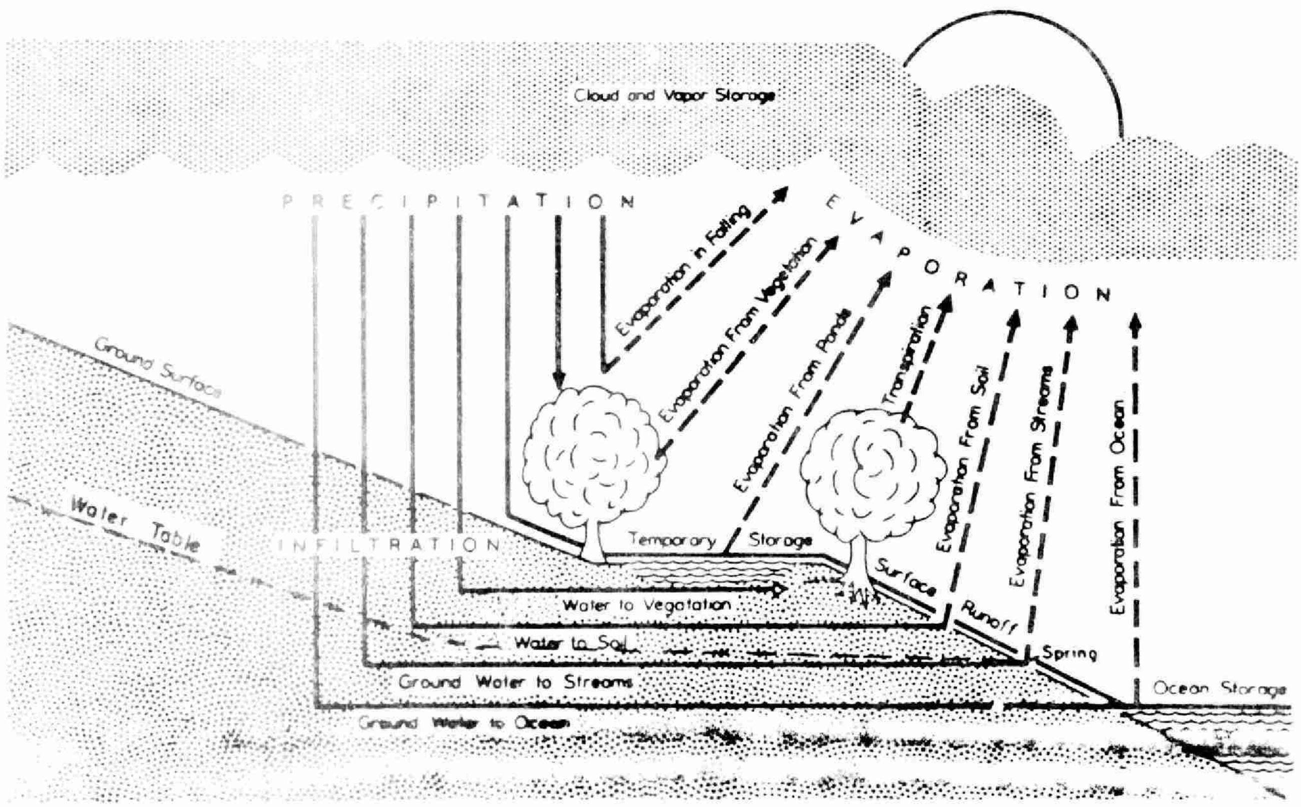



Figure 2-1 THE HYDROLOGIC CYCLE

Disadvantages to Using Ground Water:

(1) Usually very hard; may have other minerals in solution.

(2) If polluted, may be impossible to correct.

(3) Cannot be observed directly; must be discovered and gauged scientifically.

## SOURCE AND MOVEMENT

All water comes from rain and snow deposited on the earth as a part of the *water* or *hydrologic cycle*. This cycle has been called the circulatory system of the earth. Ground water is part of this cycle.

Moisture-laden air moving over the land masses from the oceans drops about 30 inches of precipitation in the form of rain and snow on North America every year. Of this amount, 60 to 80 percent is returned to the atmosphere by direct evaporation as it falls, by evaporation from the land surface, by evaporation from bodies of surface water, by evaporation from vegetation, and by *transpiration* from the plants which draw water up from the soil through their roots. Of the remainder, another 10 to 20 percent reaches surface-water bodies directly as surface runoff. Some of the remainder infiltrates the ground to form the soil moisture which is available to vegetation and a very small amount, probably about 10 to 20 percent, moves downward to become ground water in the saturated zone.

Water in the saturated zone moves under the influence of gravity at rates of from about five feet per day to about five feet per year. It usually reappears at the surface as a spring or discharge into a stream, lake, or ocean. This fact is readily recognized when we observe rivers and streams continuing to flow after long periods of no rainfall. The rivers are being fed by ground water which drains slowly into the river channels throughout the drainage system. Only during the more intense or long rainfall periods do appreciable quantities of precipitation run off directly to streams without passing through the ground. It is very important to keep in mind that ground water and surface water are not separate and distinct but closely interrelated.

## QUALITY OF GROUND WATER

Water moving through the atmosphere and soil particles comes into contact with many soluble materials. These form chemical compounds, or salts, which are contained in solution.

Some rocks are more soluble than others. Granites, for example, are relatively insoluble but limestone, gypsum, and dolomite can be quite soluble. Over long periods of time, considerable amounts of calcium carbonate or sulphate are taken into solution from these rocks.

Ground water is usually very hard. A hardness scale in common use is as follows:

TABLE 2-1 HARDNESS SCALE

| | Hardness |
|---|---|
| Soft Water | 0-60 mg/l (ppm) of Calcium Carbonate ($CaCO_3$) |
| Medium or Moderately Hard Water | 61-120 mg/l of Calcium Carbonate ($CaCO_3$) |
| Hard Water | 121-180 mg/l of Calcium Carbonate ($CaCO_3$) |
| Very Hard Water | Greater than 180 mg/l of Calcium Carbonate ($CaCO_3$) |
| (The conversion for grains of hardness = 1 grain/Imp gal = 14.3 ppm) | |

Depending on geological conditions, ground water may also contain hydrogen sulphide, salt, or iron.

The quality of ground water can be affected by careless waste disposal; ground-water supplies that are polluted may be difficult or impossible to correct.

Although we are becoming aware of the dangers of surface water pollution, "out of sight, out of mind" can be the guiding rule for buried wastes. These wastes do not disappear; they can seep downward and penetrate the ground-water table. Here the contaminated liquids can be drawn into a pumping well which would then have to be abandoned.

Keeping decomposable trash from being used to fill abandoned gravel pits is a real and present danger and many serious contamination problems can result if the practice is not prevented or properly controlled.

In the United States, some states have very serious ground-water pollution problems with large water supplies made useless due to careless waste disposal with no regard for contamination of ground water.

## STORAGE

As part of the hydrologic cycle, ground water is a renewable natural resource; the amount that finally flows out on surface or is extracted by means of wells is usually replaced every year. If we assume that about 20 percent of the precipitation that reaches the earth's surface infiltrates the ground, this would mean that for every square mile of land surface, 250,000 gallons of water per day would infiltrate. This figure, however, is controlled by such factors as surface formations, soil type, vegetal cover, and ground formations. Where sand and gravel deposits are present at surface or where bedrock formations with their weathered surfaces outcrop, a maximum amount of infiltration will take place. On the other hand, surface deposits of clay or *clay till* will contribute to a greater amount of surface runoff.

Ground water is stored in the pore spaces between the sand and clay particles and in the crevices and solution channels of the rock formations. Poorly-sorted sand, gravel, silt, and clay materials (such as occur in glacial till, where large and small particles of soil are mixed together) have a smaller proportion of pore space to store water than do well-sorted materials where all the grain sizes are equal.

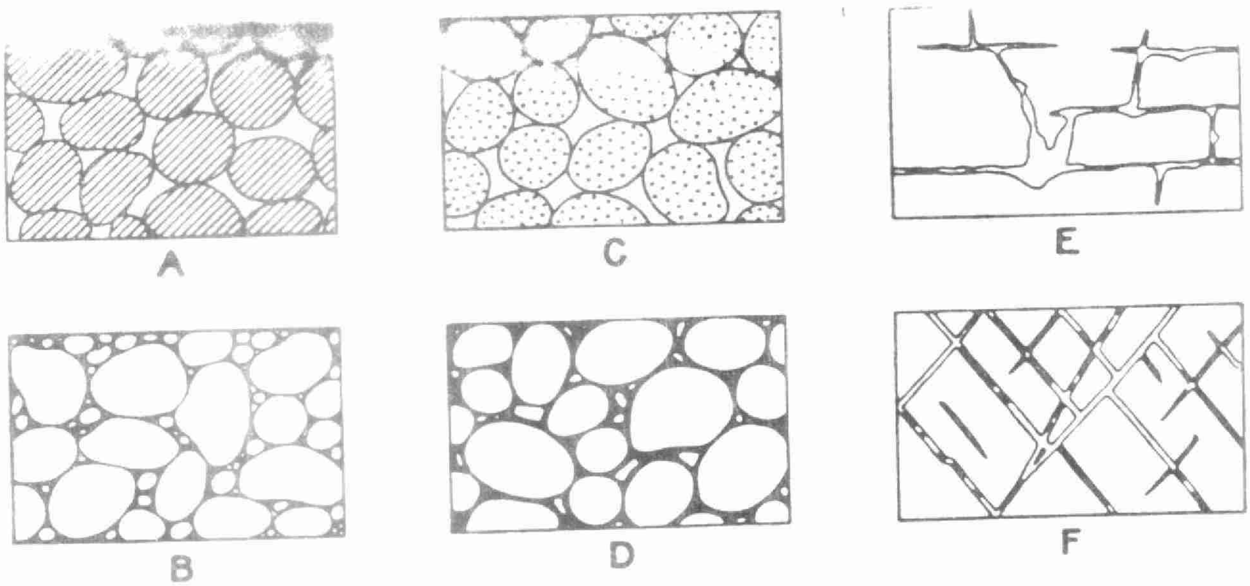
A general range in porosity of natural sediments and sedimentary rocks is given in Table 2-2.

TABLE 2-2

POROSITY OF NATURAL SEDIMENTS AND SEDIMENTARY ROCKS

| Materials | Porosity Percent |
|---|---|
| Sandstone | 4-30 |
| Sand, Clean and Uniform | 30-40+ |
| Gravel, Clean and Uniform | 30-40+ |
| Sand and Gravel Mixed | 15-25 |
| Silt and Clay | |
| As Deposited | 40-90 |
| Compacted and Dewatered | 20-40 |
| Shale | 1-35 |
| Limestone | 1-50 |

A formation may contain many pore spaces which contain a great deal of water, but if the pores are small or are not connected so water can flow freely from one pore to another, the formation may yield only a small amount of water. This introduces the second very important factor used in determining how a formation will act as a source of water. It is called *permeability* or the *ability of soil or rock to transmit fluids.* A formation such as sand and gravel or creviced limestone which has many pore spaces large enough and interconnected to allow ground water to move freely through them is called an *aquifer.*




A—Well-sorted sedimentary deposit having high porosity.

B—Poorly sorted sedimentary deposit having low porosity.

C—Well-sorted sedimentary deposit consisting of pebbles that are themselves porous; the deposit, as a whole, has a very high porosity.

D—Well-sorted sedimentary deposit whose porosity has been diminished by the deposition of mineral matter in the interstices.

E—Rock rendered porous by solution.

F—Rock rendered porous by fracturing.

Figure 2-2

Diagram showing several types of rock interstices and the relations of rock texture to porosity.

The amount of water stored in these aquifers or ground-water reservoirs has not been fully determined. The Ministry of the Environment and government agencies in several other provinces, notably Alberta and Saskatchewan, are stepping up their collection of basic data and making an inventory of ground-water conditions by means of geologic and hydrologic surveys.

The Precambrian granites and other rock types underlie 60 percent of the area of the Province, chiefly in northern Ontario. As a rule, these formations are classified as poor aquifers. Wells may obtain sufficient water for average domestic needs from joints, cracks, or fracture planes near the surface of these rocks but high-capacity wells are confined almost entirely to the sand and gravel deposits in the overburden above them making them gravel wells.

The limestones and dolomites of southern Ontario vary widely in their water yielding properties. They often make better aquifers in the southwestern parts of the Province than they do in south-central or eastern Ontario. The quality of the water is generally very hard and is often highly mineralized with sulphur compounds, particularly in the areas closest to Lakes Erie and Ontario and the St. Lawrence River.

The shale formations yield only small quantities of water but the water is much softer than that from the limestone rocks. Salty water is frequently encountered at shallow penetrations of the shale formations.

| Characteristics | Type of Well | | | | | |
|---|---|---|---|---|---|---|
| | Dug | Bored | Driven | Drilled | | Jetted |
| | | | | Percussion | Rotary | |
| Range of practical depths (general order of magnitude) | 0–50 feet | 0–100 feet[1] | 0–50 feet | 0–1000 feet | 0–1000 feet | 0–100 feet |
| Diameter | 3–20 feet | 2–30 inches | 1¼–2 inches | 4–18 inches | 4–24 inches | 4–12 inches |
| Type of geologic formation: | | | | | | |
| Clay | Yes | Yes | Yes | Yes | Yes | Yes |
| Silt | Yes | Yes | Yes | Yes | Yes | Yes |
| Sand | Yes | Yes | Yes | Yes | Yes | Yes |
| Gravel | Yes | Yes | Fine | Yes | Yes | ¼" pea gravel |
| Cemented gravel | Yes | No | No | Yes | Yes | No |
| Boulders | Yes | Less than well diameter. | No | (In firm bedding) | (Difficult) | No |
| Sandstone | Soft | Soft | Thin layers | Yes | Yes | No |
| Limestone | Soft, fractured | Soft, fractured | No | Yes | Yes | No |
| Dense igneous rock | No | No | No | Yes | Yes | No |

[1] The ranges of values in this table are based upon general conditions which may be exceeded for specific areas

TABLE 2-3 CHARACTERISTICS OF VARIOUS TYPES OF WELLS

A wide variety of *overburden* conditions is present in Ontario. Although much of the area is covered on the surface of the ground with clay or till materials, numerous deposits of sand and gravel are present to provide suitable aquifers in most places for average domestic needs. Areas where there are high-capacity wells for municipal, industrial, or irrigational purposes are less common.

## EXTRACTION OF GROUND WATER

Aside from the use of naturally occurring springs, ground water is recovered by means of dug, bored, driven, and drilled wells. Although there are more dug wells in use today than any other type, the number of drilled, driven, and bored wells is increasing as a result of improved methods of well construction and the need for deeper wells which provide a more dependable supply of water. The dug, bored, and driven types of wells are normally the least satisfactory because they are usually the shallowest, are most easily contaminated and are affected by variations in ground-water levels. These types of wells work best in areas where there are sand and gravel in the overburden. Under these conditions, the porosity and permeability of the aquifers allow water to move into the well quickly to replace that which is withdrawn. Dug, bored, and driven wells in areas of tight clay overburden are often without water because the transmissibility of the clay is so low that water will not flow into the well readily; however, a few sandy seams in the clay will sometimes keep the well supplied.

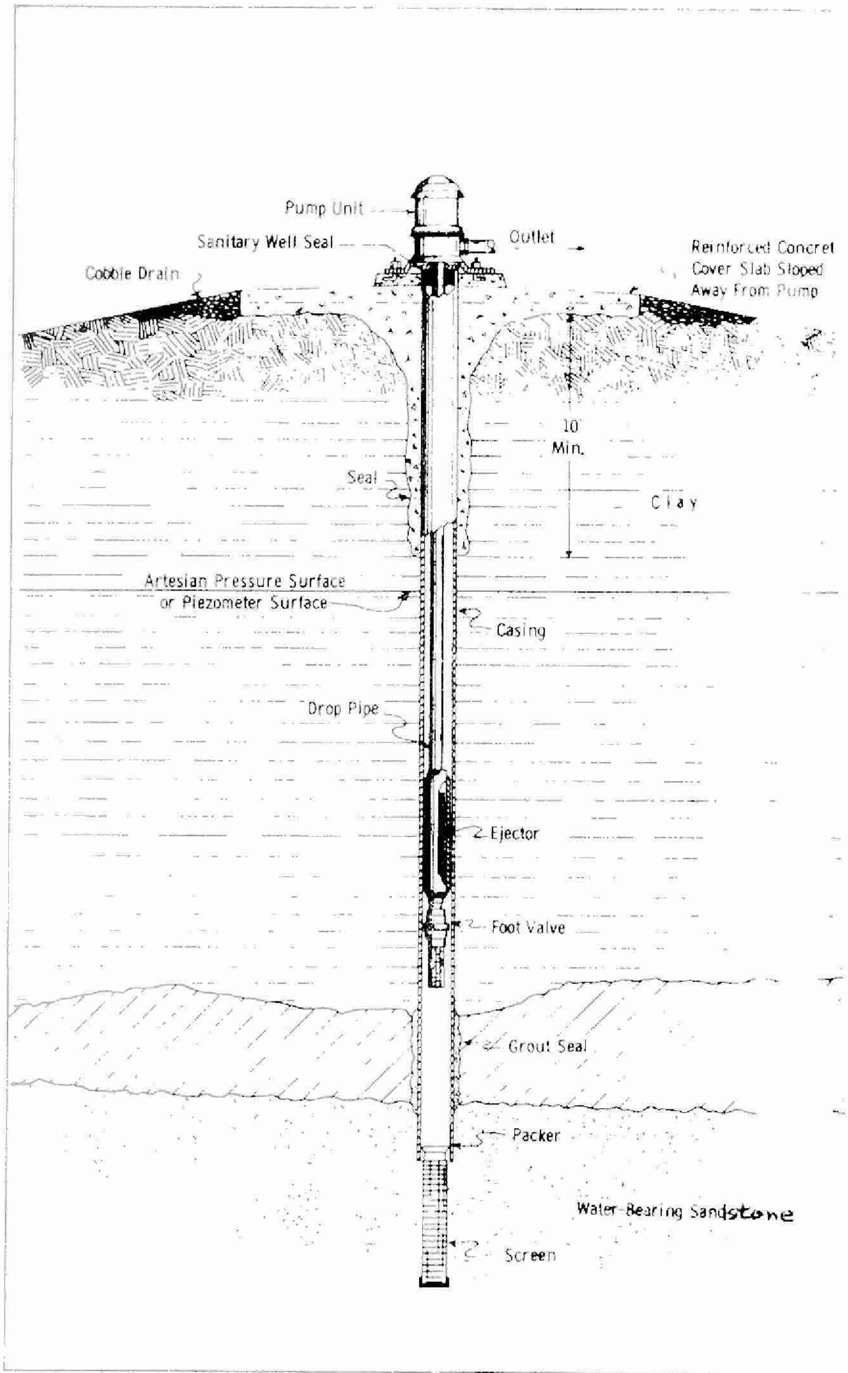



Figure 2-3 DRILLED WELL

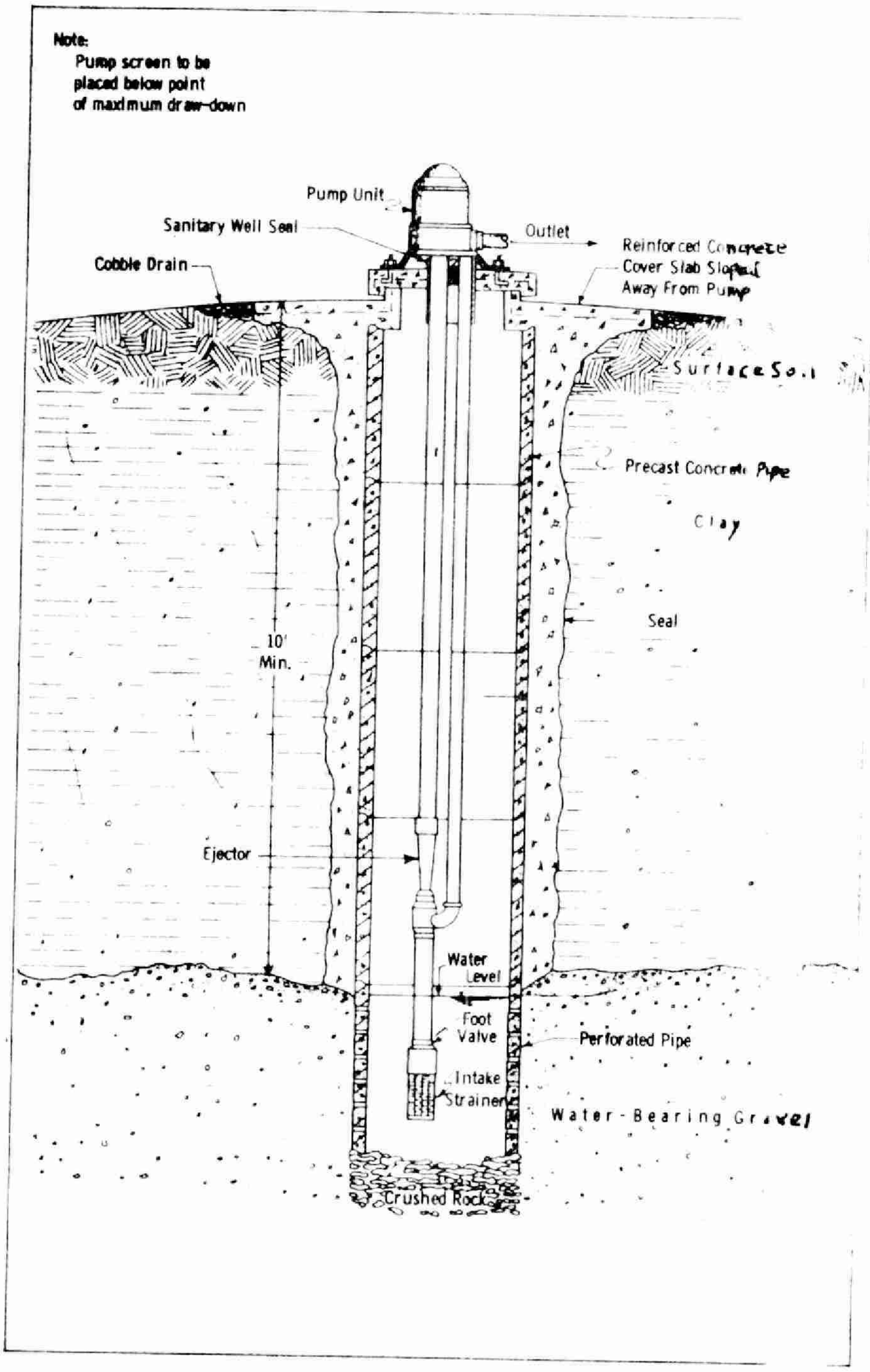



Figure 2-4 Bored Well

Often more reliable sources of water supply are available from drilled wells. Drilled wells usually extend deeper than dug wells into what are known as *artesian aquifers*. This means that the water is coming from an area in the overburden or the bedrock that has more "head". The water in a well drilled into an artesian aquifer rises up above the level where it was first encountered, because of the pressure behind it. If the pressure head is great enough, the well will flow. The flowing well is not an indication that the well is good but that the well head is lower than the pressure head of the water in the aquifer at that point.

Since the only information we are sure of before drilling is the amount of water needed from the well, one or more test holes are usually required. Test holes often become the finished well and are the only sure way to discover (1) *Quantity* of water available, (2) *Chemical quality* of water, and (3) Cost to develop well and produce water from the well.

In *rock wells* several holes may be drilled before intersecting a solution channel or fracture in the bedrock. The test hole that finally intersects this channel or fracture would become the final well.

Drilled wells ending in sand and gravel are sometimes developed with an artificial gravel pack to reduce the velocity of water flow into the well. This helps to keep the water free from sand and silt and the screen free from materials precipitating out of solution. Other wells drilled into sand and gravel are developed naturally with no gravel pack. The rock well requires no screen and, therefore, usually requires less maintenance and rehabilitation, (see figures on page 2-26).

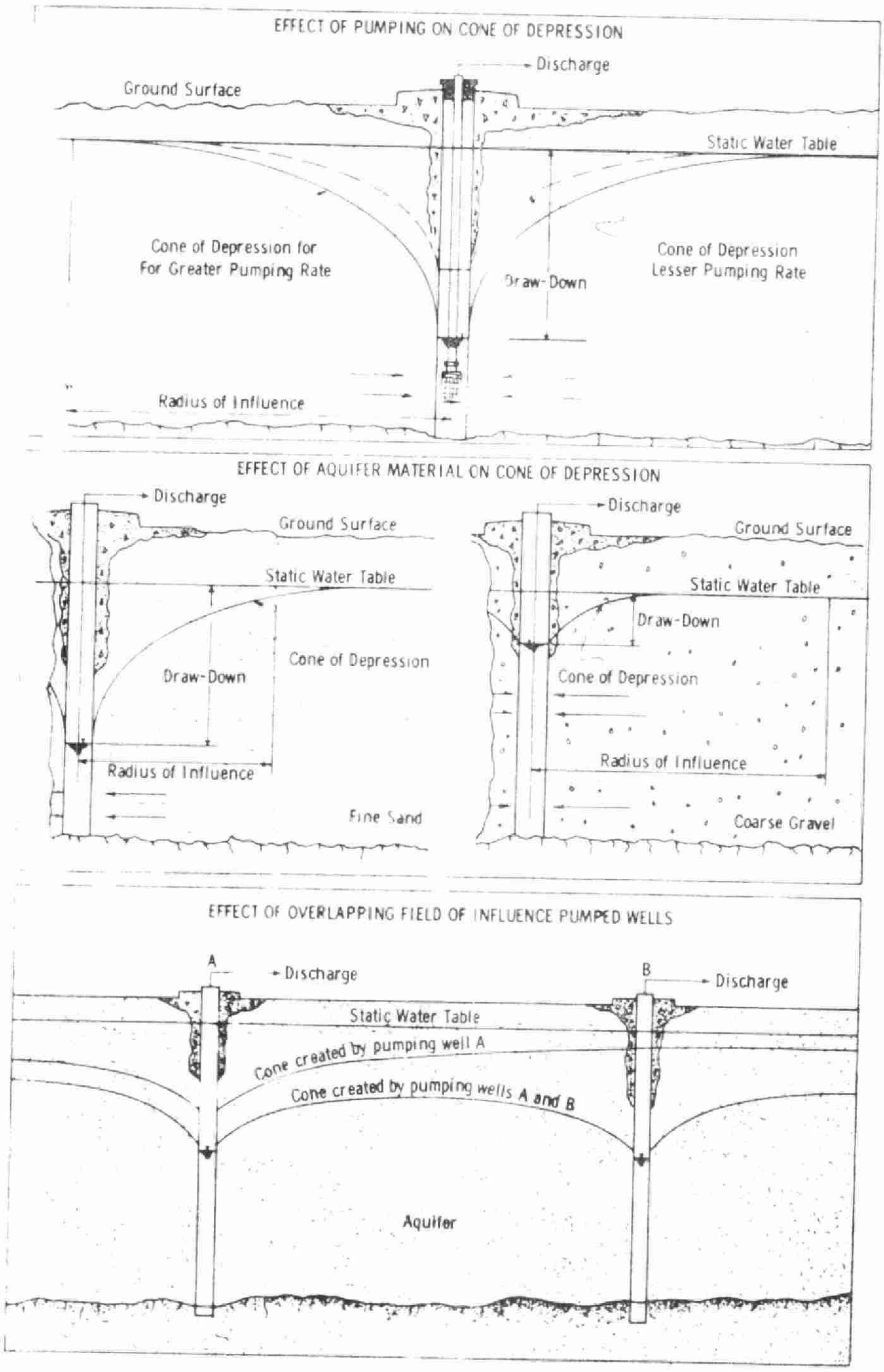



Figure 2-5 PUMPING EFFECTS ON AQUIFERS

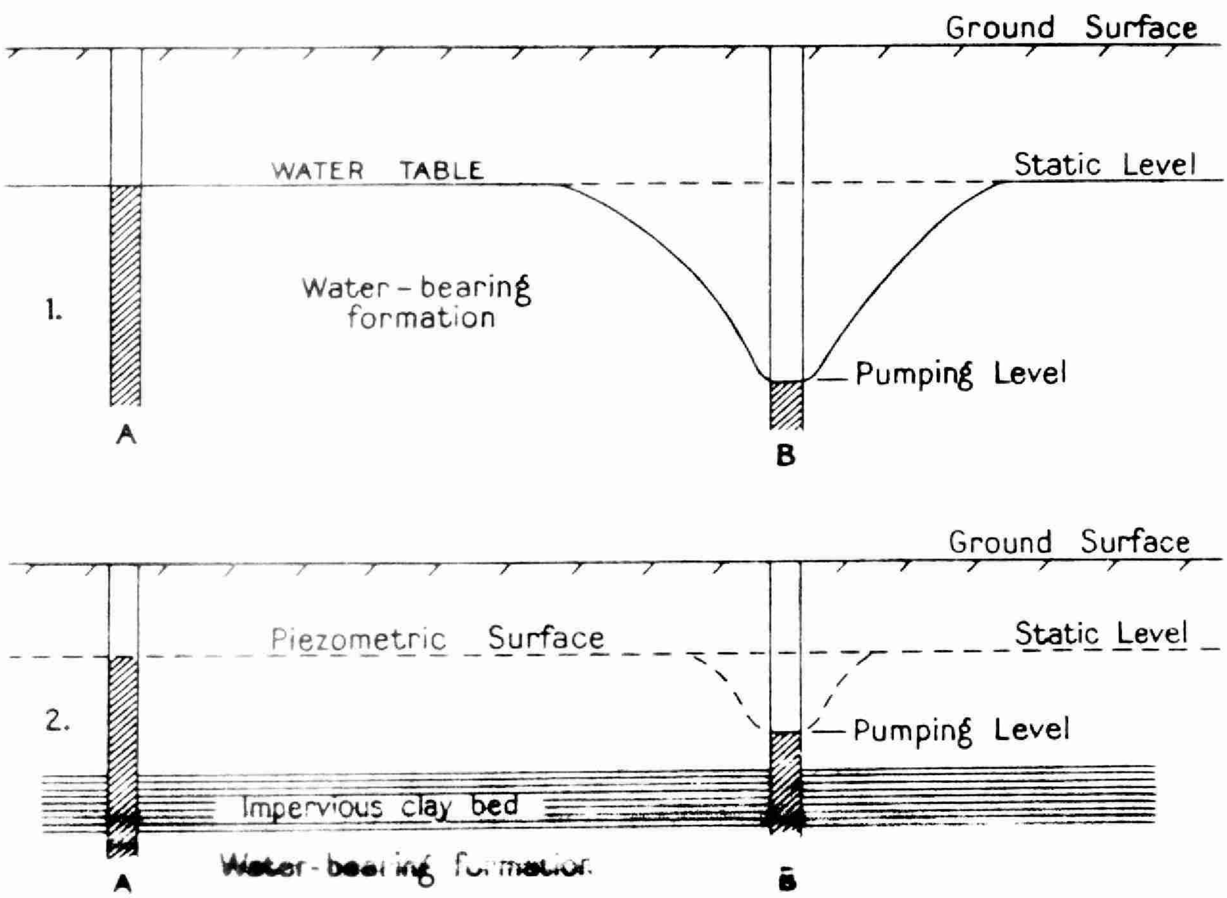



Figure 2-6 Showing the effect of a pumped well on the water levels in adjacent wells under water-table and artesian conditions.

When water is pumped out of a well, the lowering of water pressure at the well site causes water in the aquifer to flow towards it. It is only natural that there will be a lowering of the water level or water pressure in the vicinity of any pumped well. This lowering forms a *cone of depression* which varies in size according to the rate at which the well is pumped and the permeability of the aquifer. In a *water-table aquifer* (that is, one that is not under pressure), pumping will actually cause a dewatering of the aquifer itself and the cone of depression will spread very slowly. In an *artesian* or *confined aquifer* under pressure (the type into which many of our municipal drilled wells are constructed), the cone of depression is an imaginary pressure surface that spreads out rapidly. The effect of pumping can be observed several hundred or thousand feet away in a few minutes.

When a well is constructed, a pumping test should be run to determine the permeability and storage coefficients of the aquifer. These coefficients indicate how fast the aquifer allows the water to move through it and how much of the water stored in the pores and crevices of the saturated formation is available for use. On the basis of the information obtained from the pumping test, it should be possible to give a fairly accurate rating to the capacity of the well. In such tests, many readings should be taken of water levels in the pumped well and preferably one or more gauge holes, particularly during the early part of the pumping test.

After a well has been put into use, the following observations should be made as regularly as possible:

(1) Daily quantity pumped

(2) Daily pumping level

(3) Daily discharge pressure

(4) Weekly static level

Unless these data have been recorded in a careful and orderly manner, it is very difficult to assess the cause of well failures and production decreases.

## WELL MAINTENANCE

The operation and maintenance of a well supply are a great responsibility. A pump gets attention because at least some of its working parts are above ground. A well on the other hand, because it is underground and out of sight, is often overlooked until trouble seriously affecting the quantity of water supplied to the pump, demands immediate and perhaps costly action. Systematic operation and preventative maintenance, properly worked out for the specific conditions in a locality, can improve overall performance and increase the life of wells.

Before anyone can properly operate or maintain a water well, he should know the following:

1. the methods and materials used in constructing wells.
2. the local water-bearing formations or aquifers and their hydrologic characteristics.
3. the quality of ground water and its effect on well materials.

4. the probable causes of well troubles, how to discern them and what can be done to eliminate them.

Well construction, well hydrology and hydraulics, the effects of water quality, the probable causes of well failure and how to recognize their occurrence and remedy them are large subjects in themselves and are beyond the immediate scope and requirements of this course. Without going into details, the following protective measures should be considered to maintain and protect a ground-water supply:

1. All wells should be located and constructed by men experienced in this type of work who understand the occurrence and movement of ground water in the various water-bearing formations. Improper construction and improper rating have been the cause of many well failures.
2. All wells should be located so that they will not interfere seriously with other wells operating in the vicinity.
3. All wells and pumping equipment should be constructed of materials that will resist the corrosive and erosive action of the water being pumped, as well as the action of chemicals which may be used to remove accumulations.
4. All wells should be operated at their most economical and efficient point by equipping them with pumps properly designed for the characteristics of each well.

5. Water samples should be collected and analyzed regularly and periodically for chemical and bacteriological quality. The quality of the water may change slowly as the well is used. It may improve or it may get worse, depending on the geologic and hydrologic conditions of the area. Chemical analysis may indicate whether incrustation likely is occurring and what steps should be taken to prevent serious plugging of the well.

6. Last and possibly most important is the keeping of good records of well operation. Accurate records of the history of the well undoubtedly provide the soundest basis for deciding just what preventive maintenance procedures would likely be most worthwhile.

A carefully conducted pumping test carried out in the prescribed manner at selected intervals is also advisable. Such test, when interpreted in the light of good data on the past history and known changes, assist greatly in developing practical maintenance procedures.

## WELL STIMULATION

In most instances the advice of experts should be consulted before attempting a well improvement program. Some methods used are in Table 2-4.

These methods would be used in the event the *static level* is constant but the *pumping level* either drops rapidly, or is beginning to drop lower daily, making water extraction more expensive as well as indicating future failure.

TABLE 2-4

APPLICATIONS OF VARIOUS WELL STIMULATION METHODS

| Method | Unconsolidated Aquifers | Limestone or Dolomite Aquifers |
|---|---|---|
| Surging | Removes plugging deposits of clay, silt and fine sand in areas adjacent to screens | Rarely used |
| Jet Cleaning | Removes encrusting minerals, clay, silt and fine sand in areas adjacent to screens | Rarely used |
| Dynamiting | Vibratory explosion may be effective if carefully used | Effective under some conditions |
| Hydraulic Fracturing | Not usually used | Particularly effective in rocks with tight fractures |
| Acidizing | Removes iron, sulphur and carbonate deposits | Sometimes beneficial. Best results obtained by pressure acidizing |
| Caustic Soda | Removes oil scum left by oil-lubricated pumps | Removes oil scum left by oil-lubricated pumps |
| Chlorination | Removes iron and slime-forming bacteria | Removes iron and slime-forming bacteria |
| Polyphosphate followed by chlorine | Removes fine silt, clay, colloids, disseminated shale and soft iron deposits | Not usually effective |

NATURAL RECHARGE

If we consider that about 12 inches of water are available annually from precipitation for use in our streams and ground water, and if we assume that at least one half of this amount infiltrates the ground to an aquifer, we can better understand where the recharge comes from that replaces the water removed by pumping. An interesting fact is that the average annual recharge period extends from November to May. Most of the rain that falls during the summer and fall months never reaches the zone of saturation because it is used up mostly as soil moisture.

If the static level (the level to which the water rises when the well is not being pumped) is gradually lowering in a well, it indicates that more water is being removed from the aquifer than is entering by natural recharge. The lowering of ground-water levels in the vicinity of pumped wells is not necessarily something to be alarmed about, provided that at some time, the ever widening cone of depression finally includes sufficient recharge to balance the withdrawals. This may take place if the cone extends to intersect a body of surface water.

Just as in a surface reservoir or lake, it is perfectly feasible to draw on stored water during periods of drought with a consequent lowering of the water level, a similar withdrawal from storage in an aquifer would lower the level of the water table. The falling water tables we hear about are not unexpected during periods of low recharge; however, during wet years the storage tends to be replenished.

Water levels that continue to lower and do not show the effect of recharge indicate the mining of ground water. The continuation of such an overdraft will either lower the water level to the limit of economic lift or will exhaust the stored water.

ARTIFICIAL GROUND WATER RECHARGE

Some of the purposes for which artificial recharge is practiced are as follows:

1. Supplement the quantity of ground water available.
2. Reduce or eliminate the decline in the water level of ground-water reservoirs.
3. Conserve and dispose of runoff and flood waters.
4. Store water to reduce costs of pumping and piping.
5. Reduce, present, or correct salt water intrusion.
6. Store clear, cool water in winter for use during the summer.
7. Allow heat exchange by diffusion through the ground.

The most common method used is simply an open pit or trench in which available water is allowed to percolate downward into the dewatered or unsaturated aquifer. Care must be taken that the recharge water, if not of high quality, will be filtered sufficiently by the sand and gravel in the trench so that the ground water quality will be protected. Sand and gravel may be placed in the trench or pit very much like filter media in a water treatment plant. Lining, the size of pea gravel, has been effective.

Abandoned gravel pits, dry stream beds or even dried up pond sites could be used if in the right location to the aquifer needing recharge and source of supply.

The method used depends on (1) quality and quantity of available recharge water, (2) type of aquifer, and (3) what is available (probably in that order).

Sometimes there will be enough sand and gravel under the topsoil to provide good filtration. Available water may then be allowed to percolate into the aquifer for future withdrawal or to replace water mined during a drought. This method will not work if the aquifer is capped with clay or other impervious material.

Another method, that of injecting water to aquifers by means of recharge wells, is expensive and is used primarily when some other benefit besides recharge is to be gained. For example in California and Israel, injection wells dispose of cooling water or storm water, to allow for an improvement in quality to an acceptable level. In sea coast areas, recharge water may be injected to prevent salt water intrusion into fresh water aquifers.

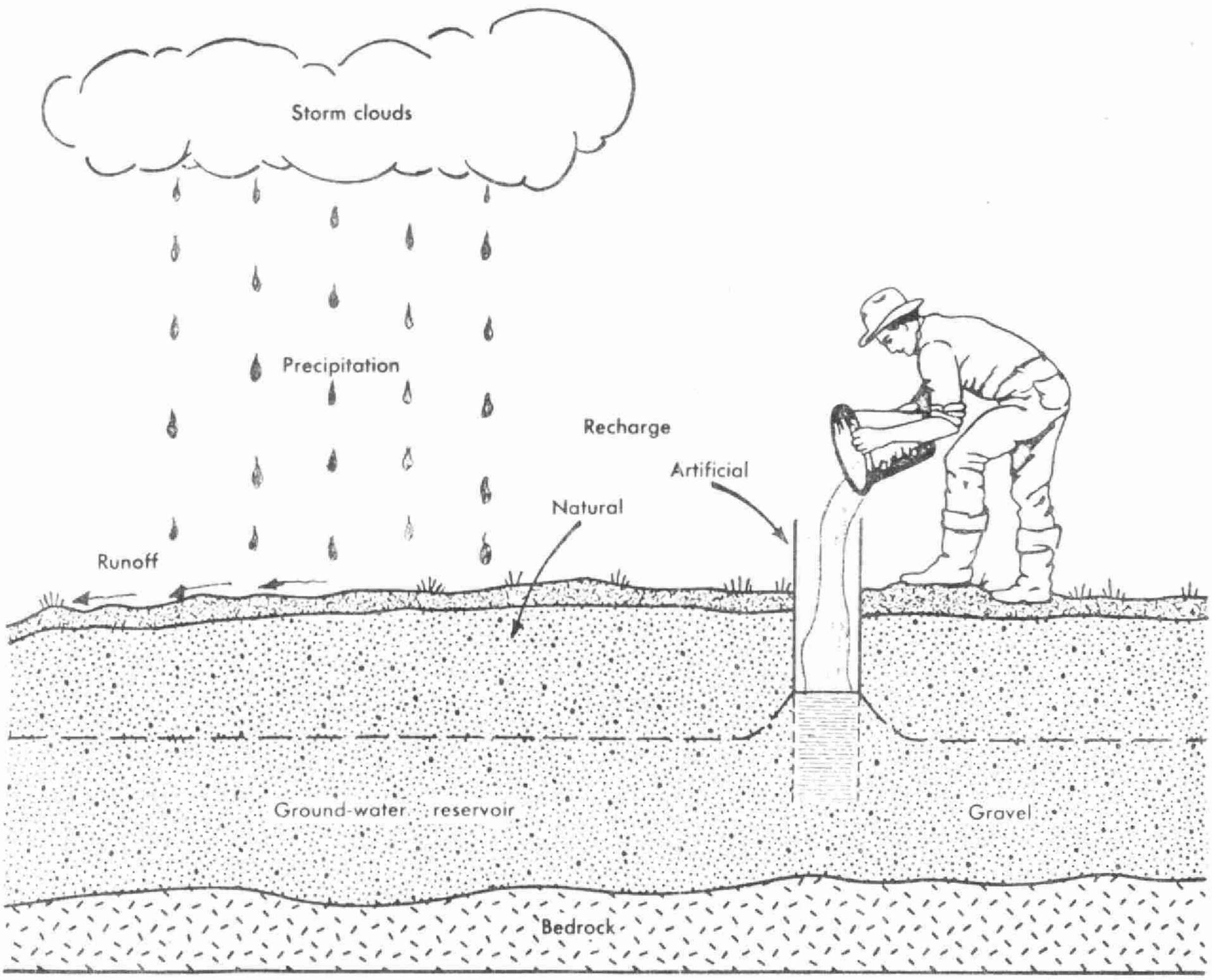



Figure 2-7 Artificial Recharge

## CONCLUSION

Future demand will call for great strides in both ground and surface water supply development. Surface and ground-water supplies are closely interrelated. Neglecting ground-water development when vast quantities are available would be uneconomical.

Operators should try to become familiar with the ground-water potentials in their area. Since every geographical area is unique in its climate-soil-water relationship, practices in one area may not be practical in another.

Future developments in recharge and methods of tapping "unreachable" supplies make education for operators even more relevant than in the past. Operators of water works owe it to themselves, their families and their communities to find out as much about the science of the water supply in their locality as possible.

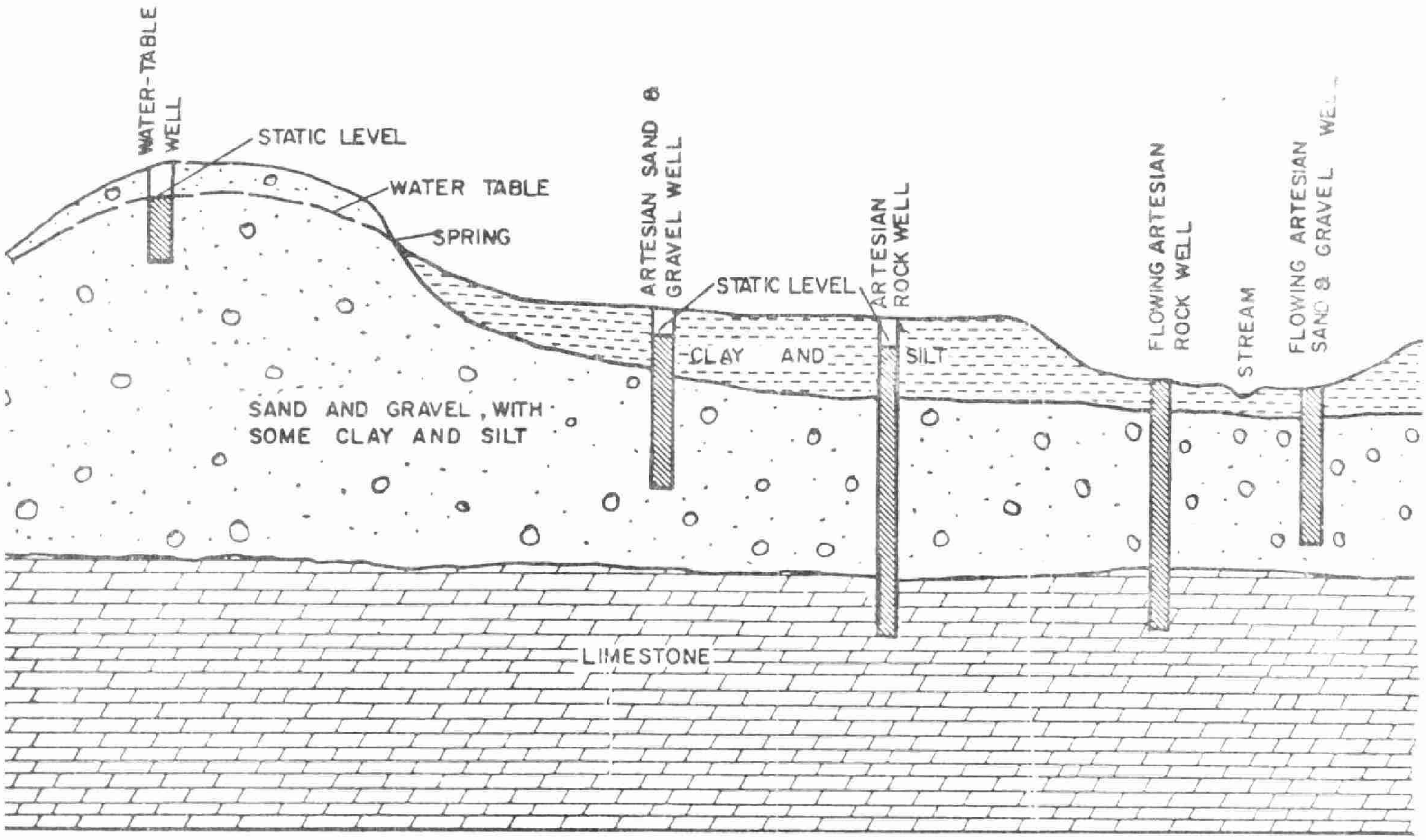
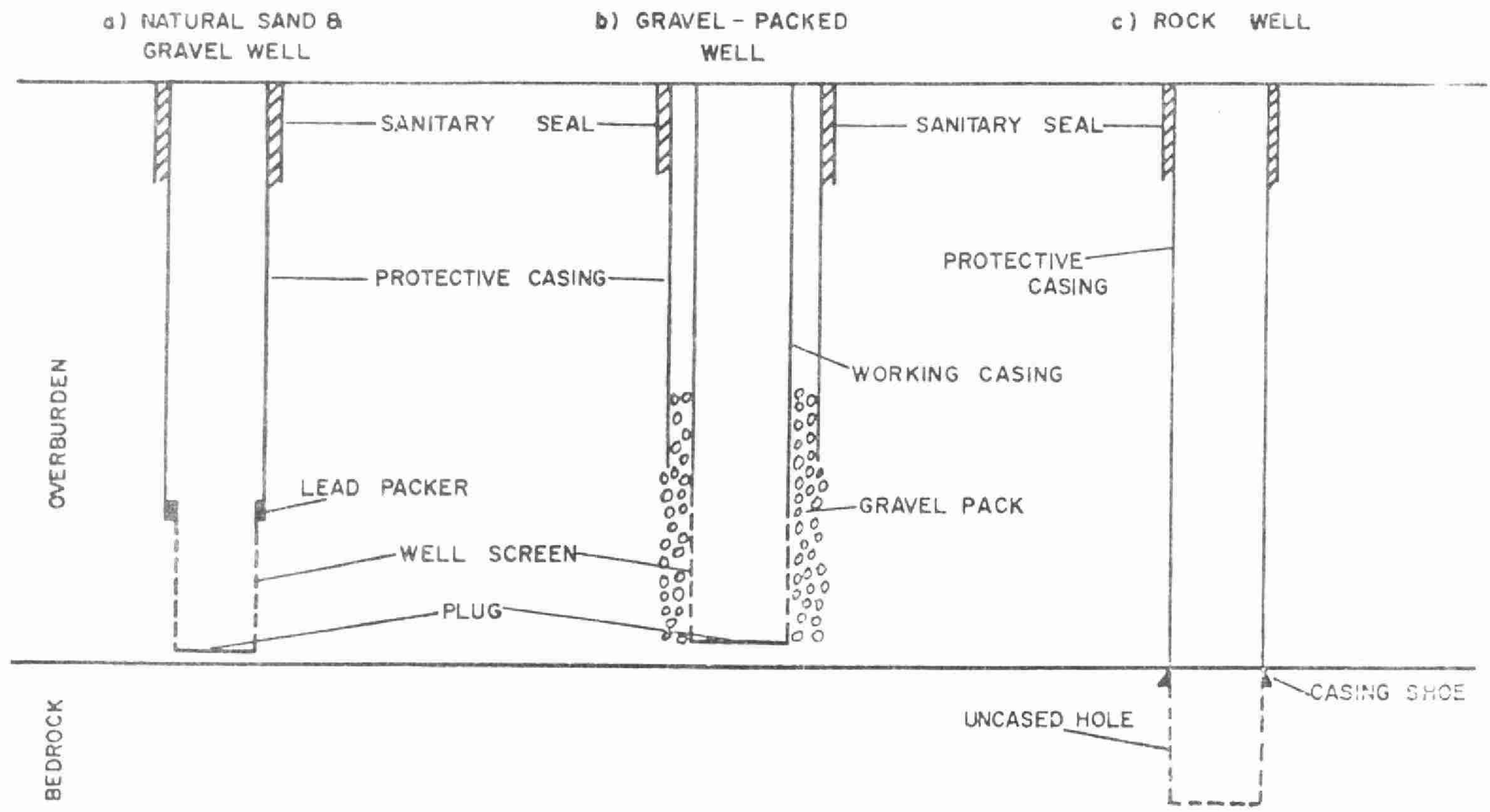



ILLUSTRATION OF WELLS COMPLETED IN OVERBURDEN AND BEDROCK FORMATIONS AND UNDER WATER-TABLE, ARTESIAN, AND FLOWING ARTESIAN CONDITIONS.




COMPONENTS OF SOME TYPICAL TYPES OF DRILLED WELLS.

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**SUBJECT:**

BASIC WATER
TREATMENT OPERATION

**TOPIC:** 3

COAGULATION, FLOCCULATION
AND SEDIMENTATION

## OBJECTIVES:

Trainee will be able to:

1. Define the following:
   turbidity
   algae
   coagulation
   flash mixing
   flocculation
   flocculation aids
   sedimentation

2. Describe, in simple terms, the coagulation and flocculation process;

3. Identify 2 different types of flash mixers;

4. Identify 4 different types of flocculators;

5. Describe the sedimentation process:
   in a conventional basin
   in a suspended solids contact basin,
   in tube settlers;

6. Outline the purpose of the jar test.

# COAGULATION, FLOCCULATION AND SEDIMENTATION

## INTRODUCTION

Three types of suspended matter (turbidity, colour and algae) are usually encountered in "surface waters" such as lakes, rivers and ponds. (Most well waters need no treatment other than disinfection.)

## NATURE OF MATTER IN WATER

Matter in water may be broadly classified according to its origin as inorganic mineral matter or organic carbonaceous material. Substances producing turbidity are often inorganic while those causing taste, odour and colour are generally organic compounds.

### Turbidity

Turbidity can be defined as matter suspended in water causing a cloudy undesirable appearance.

If left untreated, most of the smaller turbidity particles would pass through a standard filter while the larger turbidity particles would soon plug the surface of the filter causing short filter runs.

Sedimentation, even in enormous reservoirs would only partially reduce the amount of suspended matter in the water. The following chart gives you some idea of the time required.

TABLE 3-1

SETTLING TIME - PARTICLES

| Diameter of Particle microns | Order of Size | Approximate Time Required to Settle 1 foot |
|---|---|---|
| 100 | Fine Sand | 38 secs. |
| 10 | Silt | 33 min. |
| 1 | Bacteria | 55 hr. |
| 0.1 | Colloidal particle | 230 days |

25,400 microns = 1 inch

Colour

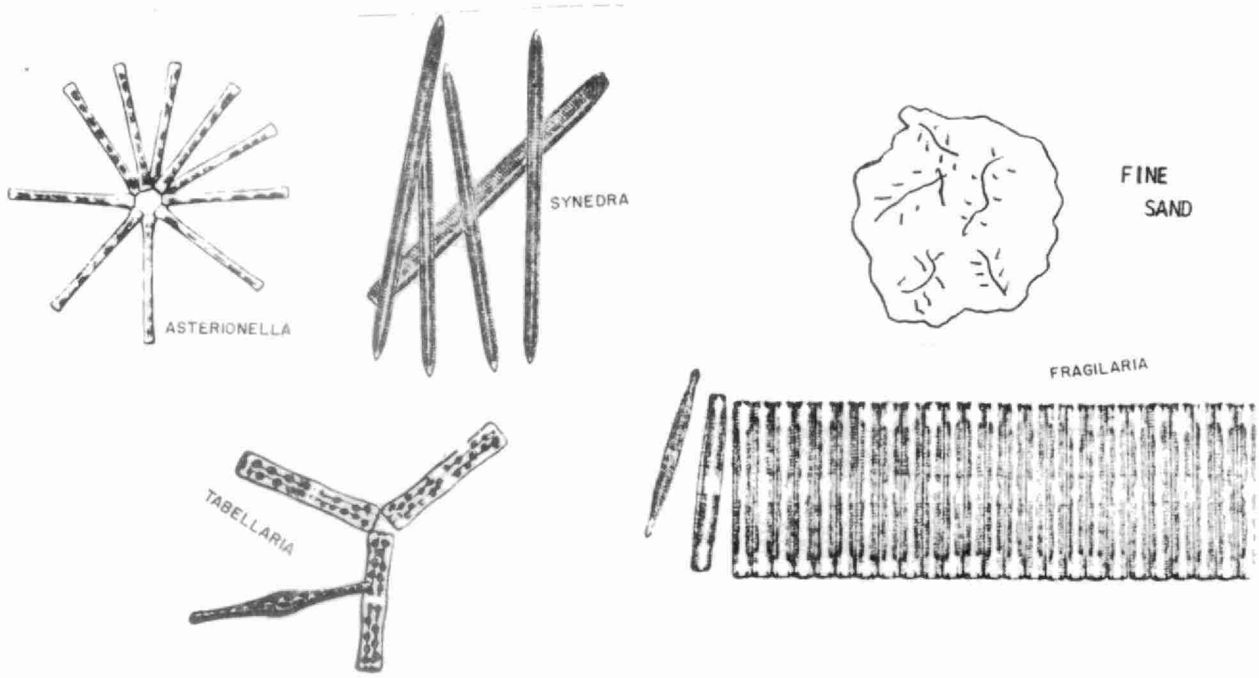
The coloured waters common to Ontario are formed when the water leaches the colour out of disintegrating woody and vegetable materials in the water. Basically coloured matter is a complex mixture of organic compounds generally present in a colloidal state like turbidity. The colloidal particles of colour are negatively charged, and are so small that standard filters will not remove them.

Algae

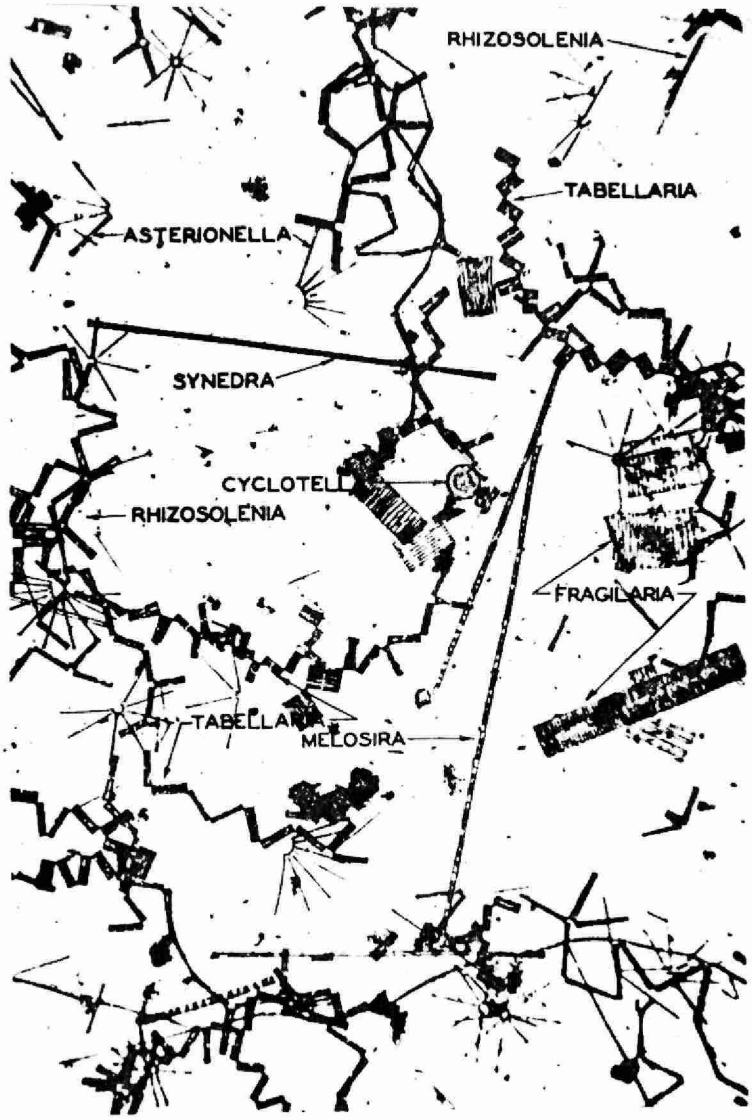
Algae are microscopic forms of plant life that can abound in surface waters, particularly during warm water periods. They come in all shapes and sizes. Algae are quite large in size compared to the colour and turbidity particles.

If the algae pass directly on to the filters, the larger types will plug the filters. Among the worst offenders for filter clogging are *DIATOMS*.

These diatoms include the following:



If they were viewed under the microscope they would look like the figure below:

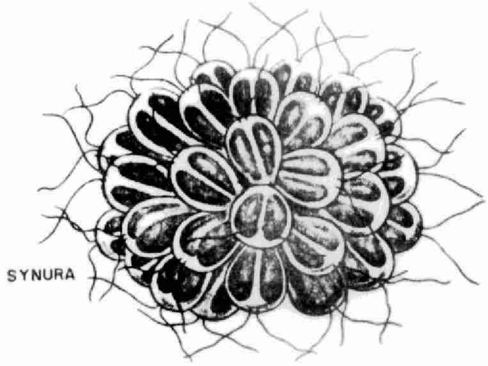



—Plankton diatoms, showing distinctive shapes of cells and colonies. The relative sizes of the various organisms are also evident in this composite photomicrograph which was furnished by J. R. Baylis, Engineer of Water Purification, Department of Water and Sewers, Bureau of Water, Chicago, Ill.

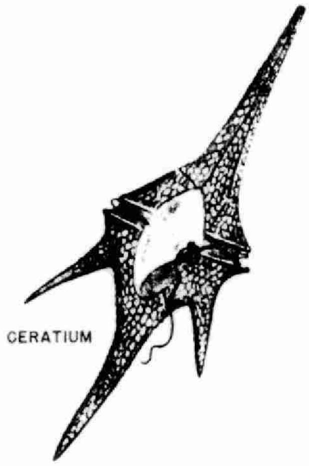
If left untreated, the smaller types of algae can pass through the filters and cause problems in the distribution system.

Algae that can lead to taste and odour problems if their numbers are sufficiently high are shown below with their associated odours:

TASTE AND ODOUR ALGAE



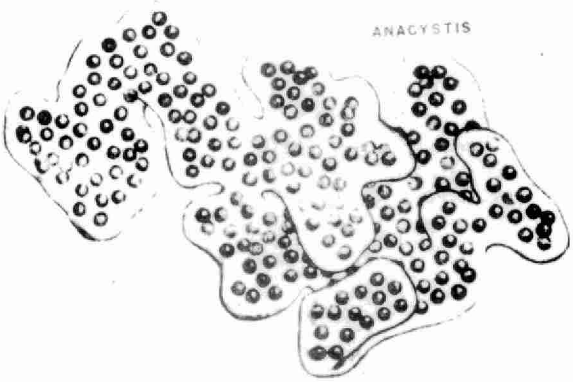

Ripe Cucumber Odour



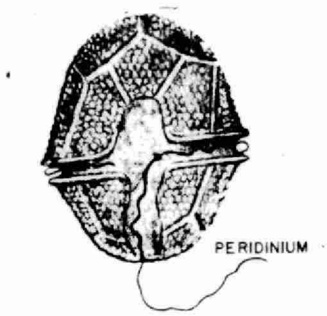

Septic Odour


Fishy Odour


Pigpen Odour




Pigpen Odour




Fishy Odour

BASIC PRINCIPLES OF COAGULATION AND FLOCCULATION

## Coagulation

Coagulants are chemicals that help collect the finely divided suspended particles in the raw water into larger clumps in a short time. These larger particles can then be settled out or removed by a filter.

Most of the water treatment plants in Ontario use one of the following chemical coagulants:

| | NAME | | CHEMICAL FORMULA |
|---|---|---|---|
| (1) | Aluminum sulphate (alum) | | $Al_2(SO_4)_3 14H_2O$ |
| (2) | ferrous sulphate | (iron salts) | $FeSO_4$ |
| (3) | ferric chloride | (iron salts) | $FeCl_3$ |
| (4) | ferric sulphate | (iron salts) | $Fe_2(SO_4)_3$ |

Since most water plants use alum as a coagulant, and since the reactions for all chemical coagulants are similar, we will discuss only alum in detail.

When alum is placed in solution, a series of reactions take place within the water itself; this series of reactions constitutes a process broadly described as *hydrolysis*.

Simplified reactions of what takes place are:

$$\underset{\text{(alum)}}{Al_2(SO_4)_3 \cdot 14H_2O} = \underset{\text{(aluminum ion)}}{2\ Al^{+3}} + \underset{\text{(sulphate ion)}}{3SO_4^{-2}} + \underset{\text{(water)}}{14H_2O} \quad \ldots.(1)$$

$$\underset{\text{(water)}}{H_2O} = \underset{\text{(hydrogen ion)}}{H^+} + \underset{\text{(hydroxyl ion)}}{OH^-} \quad \ldots.(2)$$

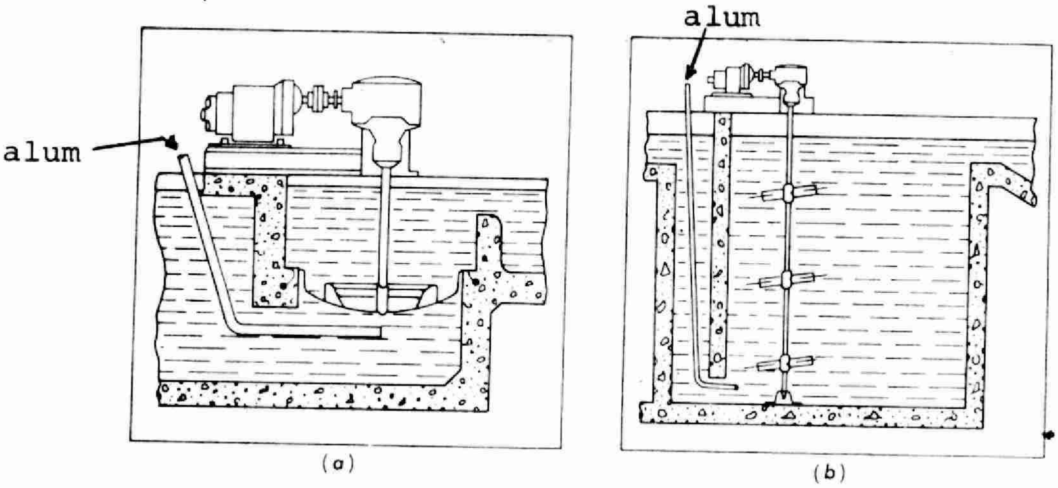
$$\underset{\text{(aluminum ion)}}{2Al^{+3}} + \underset{\text{(hydroxyl ion)}}{6OH^-} = \underset{\text{Aluminum Hydroxide}}{2Al(OH)_3} \quad \ldots.(3)$$

As the hydroxyl ions are consumed the pH decreases. Recent studies have shown that the chemistry is exceedingly complex. Billions of positively charged structures ($O^+$) move about in the water and are attracted to billions of negatively charged suspended particles:

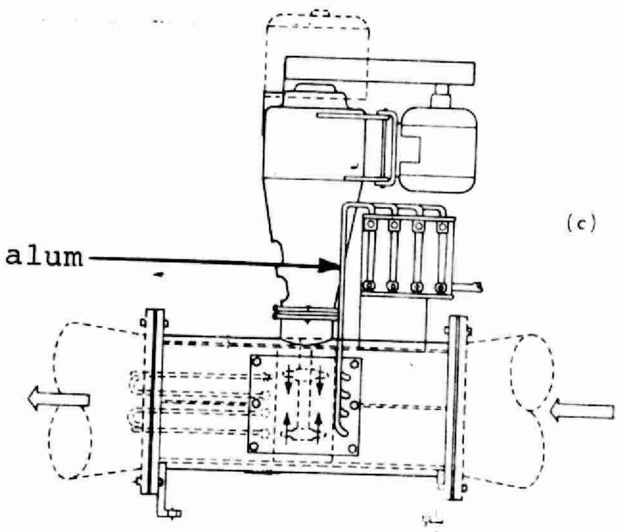
| | | | | |
|---|---|---|---|---|
| $O^+$ | $+$ | $\cdot^-$ | $=$ | $\odot$ |
| alum complex (positive charge) | | suspended matter (negative charge) | | (neutralized particle) |

*The electrical charges are neutralized and the suspended particle is stuck in the alum complex. This all takes place within the first few seconds when the alum is introduced in the water. This is essentially the entire act of coagulation.* Because it is very important that the aluminum complex ions are instantly dispersed, high speed mixers are needed. This process is called *flash mixing.*

Three different types of flash mixers are illustrated below.




MECHANICAL MIXERS
(Retention Time = 20-60 seconds)

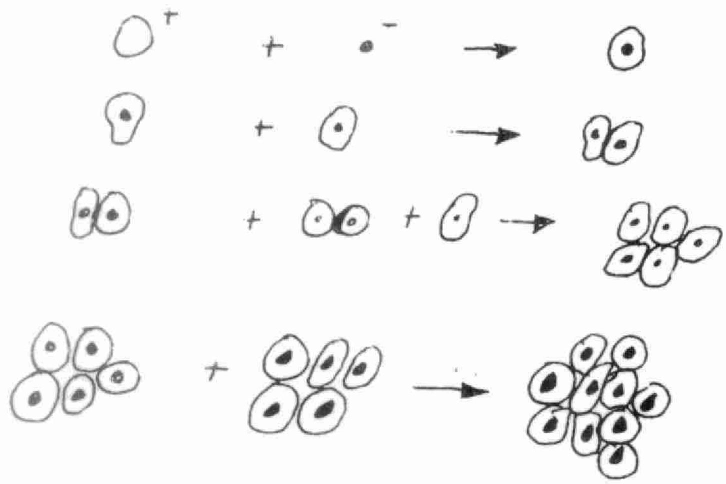



IN-LINE MIXER OR BLENDER
(Retention Time = 1-2 seconds)

After stirring at high speed for about one minute or less the particles are allowed to leave the flash-mix area. The particles then move into a second stage called the *slow mix* in the flocculation stage.

Flocculation

Flocculation is the stage of slow mixing where the small coagulated suspended particles grow through constant collision. The larger particles that are formed are called *floc*. A sketch showing how a floc is formed is shown below.

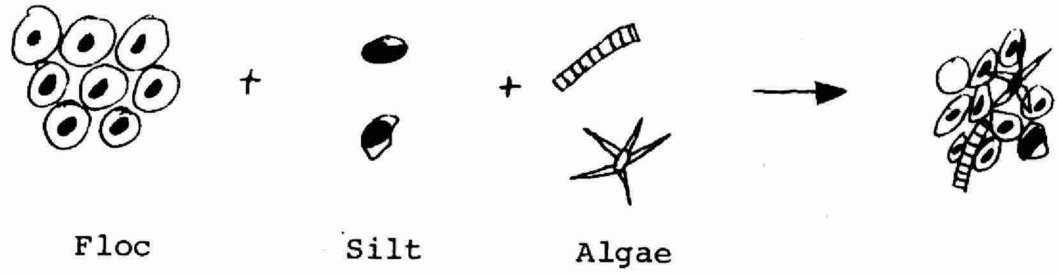


etc.

*NOTE:* *A particle collides with a second particle and they "stick" together. In turn, they collide with other particles to form a larger particle. This sticking and growing continues until a certain size is reached.*

The floc becomes larger as the time passes. The final size of the floc depends on the nature of the water and the degree of mixing. Generally, the stirring time varies from not less than 15 minutes to not more than 60 minutes.

As the floc grows, collisions with coarser suspended material and algae take place.

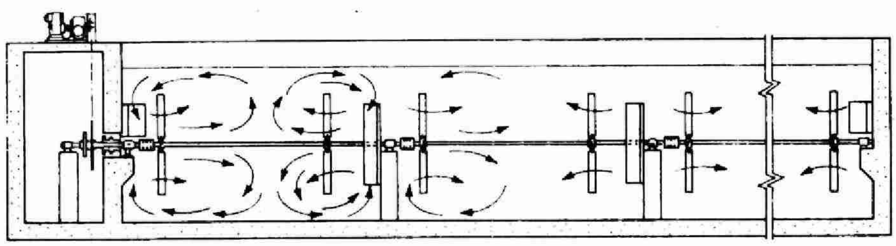



If algae are present in large numbers in the water, the floc will have a "stringy" appearance.

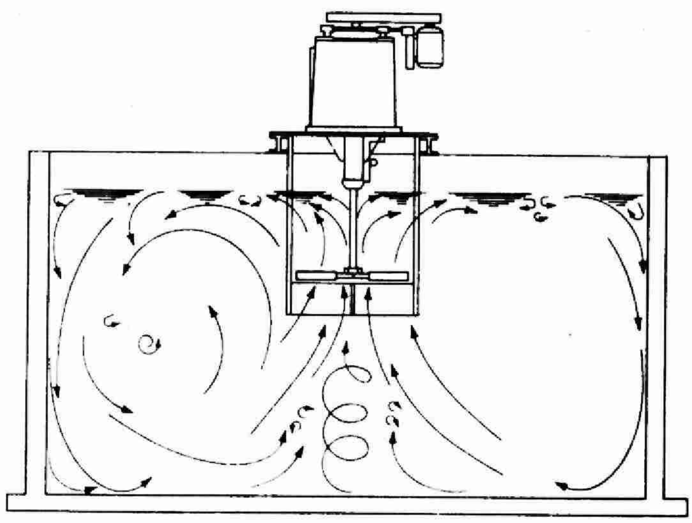
Although the floc formed contains most of the suspended matter in the water, it is still made up of approximately 96% water. Because of this, it is very fragile and must be treated gently. This means that high speed flocculation must be avoided.

## Flocculators

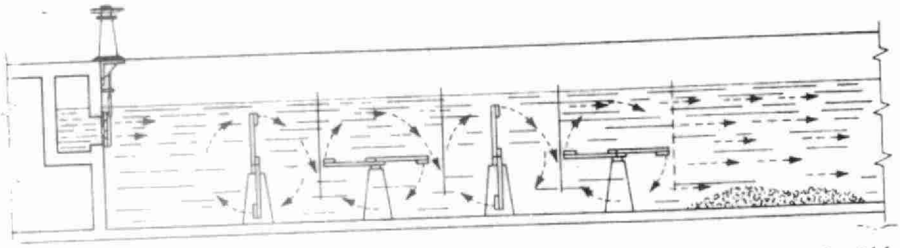
Types of flocculators include the following (a) axial-flow propeller (b) turbine (c) barrel-row motion (d) walking beam



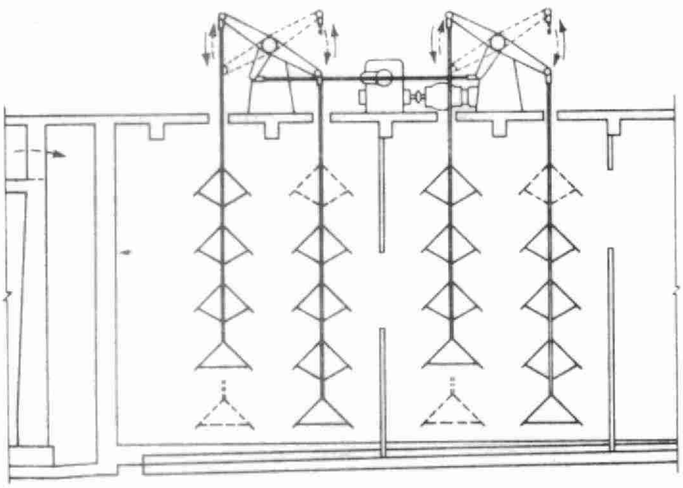
Axial-flow propeller flocculator.



Turbine flocculator. This device is easy to install in existing basins.



Flocculating equipment. A series of paddles placed transversely across the tank width are arranged to impart a barrel-roll motion to the water.



Walking beam flocculator. The up-and-down motion of the paddles provides gentle agitation.

## Flocculation Aids

Coagulation and flocculation difficulties will depend on the nature of the water being treated. These difficulties may be due to small and slow-settling flocs during low temperature coagulation, slow settling colour flocs, or fragile flocs that break up under hydraulic forces in settling basins and sand filters. Certain materials, called *flocculation aids*, are added to the water to overcome these difficulties.

Flocculation aids help form a floc that will be tougher and will settle faster. If a floc settles more rapidly, treatment plants may be able to increase their capacity without building extra facilities such as more settling basins and filters.

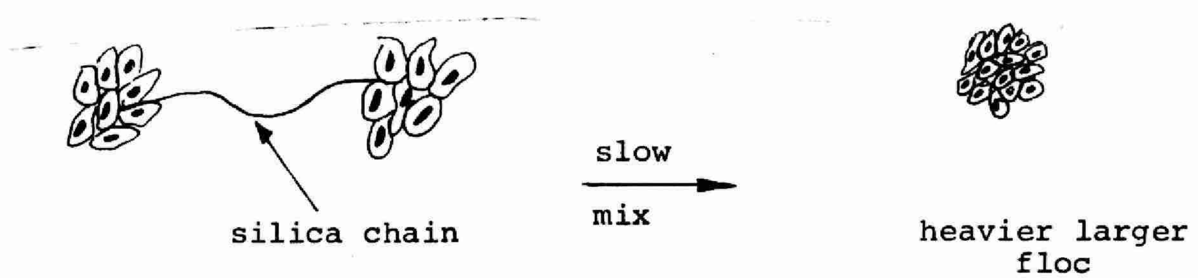
Flocculation aids include (i) adsorbants - weighting agents; (ii) activated silica; and (iii) polyelectrolytes.

(i) Adsorbants - Weighting Agents

Adsorbants - weighting agents such as *Bentonitic clays* are frequently used in treating waters containing *high colour* and *low turbidity*. When using only alum, the floc produced from these highly coloured waters is frequently too light to settle readily. The addition of clay, which is heavier, results in a "weighting action", and a more rapidly settled floc.

(ii) Activated Silica

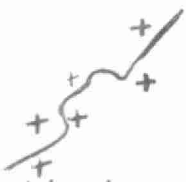
Sodium Silicate in itself is not a flocculation aid. It becomes one when part of its alkalinity is neutralized by an acid and is then considered activated. Activated silica is light blue. The exact nature of the silican compound formed during activation and its behaviour as a flocculant aid is not fully known. Some evidence suggests that during activation, polymers are formed. These polymers, being very long, can physically adsorb onto the floc and form "bridges" between particles. Activated silica should be added to the water either in the flash mixer or in the flocculation section.



(iii) Polyelectrolytes

Polyelectrolytes consist of long, linear chans of carbon atoms, colloidal in nature and action. Polyelectrolyte molecules possessing negative charges are called *anionic* while those possessing positive charges are called *cationic*. *Non-ionic* polyelectrolytes carry no electrical charges.

Charged polyelectrolytes assume a stretched-out shape in solution while non-ionic polyelectrolytes form a coil.


cationic


anionic


non-ionic

As is the case with activated silica, it is felt that the "bridging" mechanism accounts for the flocculation behaviour of these compounds.

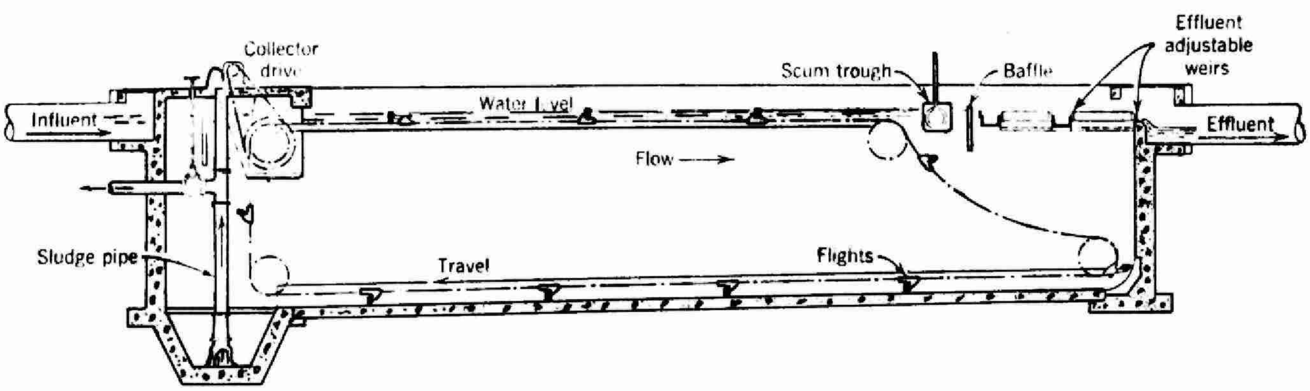
Cationic polyelectrolytes are most frequently used in water treatment because of the positive charge which, like alum, can neutralize the mainly negative charge of the impurities. For many raw waters the amount of alum used can be reduced considerably when a small amount of a cationic polyelectrolyte is added. This is because the cationic polyelectrolyte ties up some of the negatively charged colloid particles, reducing the alum requirements.

Polyelectrolytes are usually added to the flocculation section or at the inlet to the filter.

Sedimentation

Sedimentation is the separation of suspended solids from water by gravity. In treatment plants, sedimentation takes place in sedimentation basins, which may be circular, square, or rectangular. The particular shape of the basins usually depends on the area available and the experience of the engineer designing the plant. The basins should be designed so that the water can enter the basin, pass through, and leave without creating much turbulence. This permits maximum settling of suspended solids.

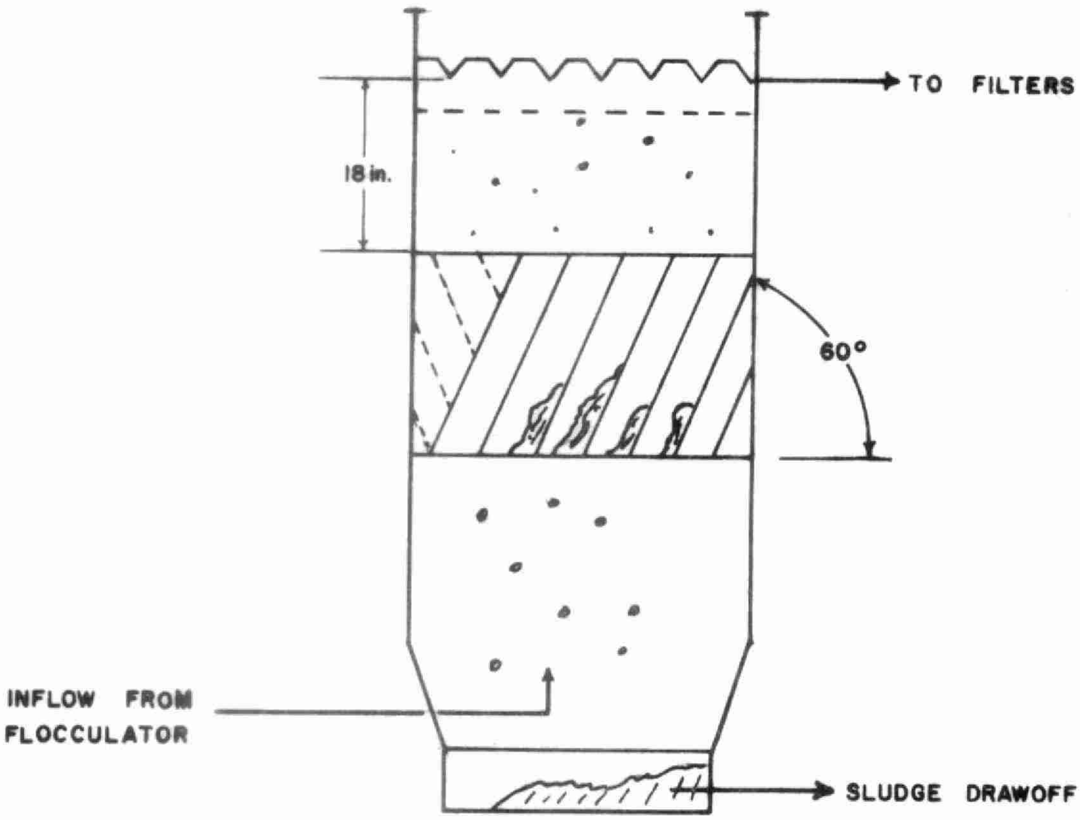
Most basins have sloped bottoms to aid sludge removal. Depths usually range from 8 to 16 feet. The time required for a unit volume of water to flow through the sedimentation basin *(retention time)* is usually a minimum of 2-2½ hours.




Rectangular Basin - Mechanically Cleaned

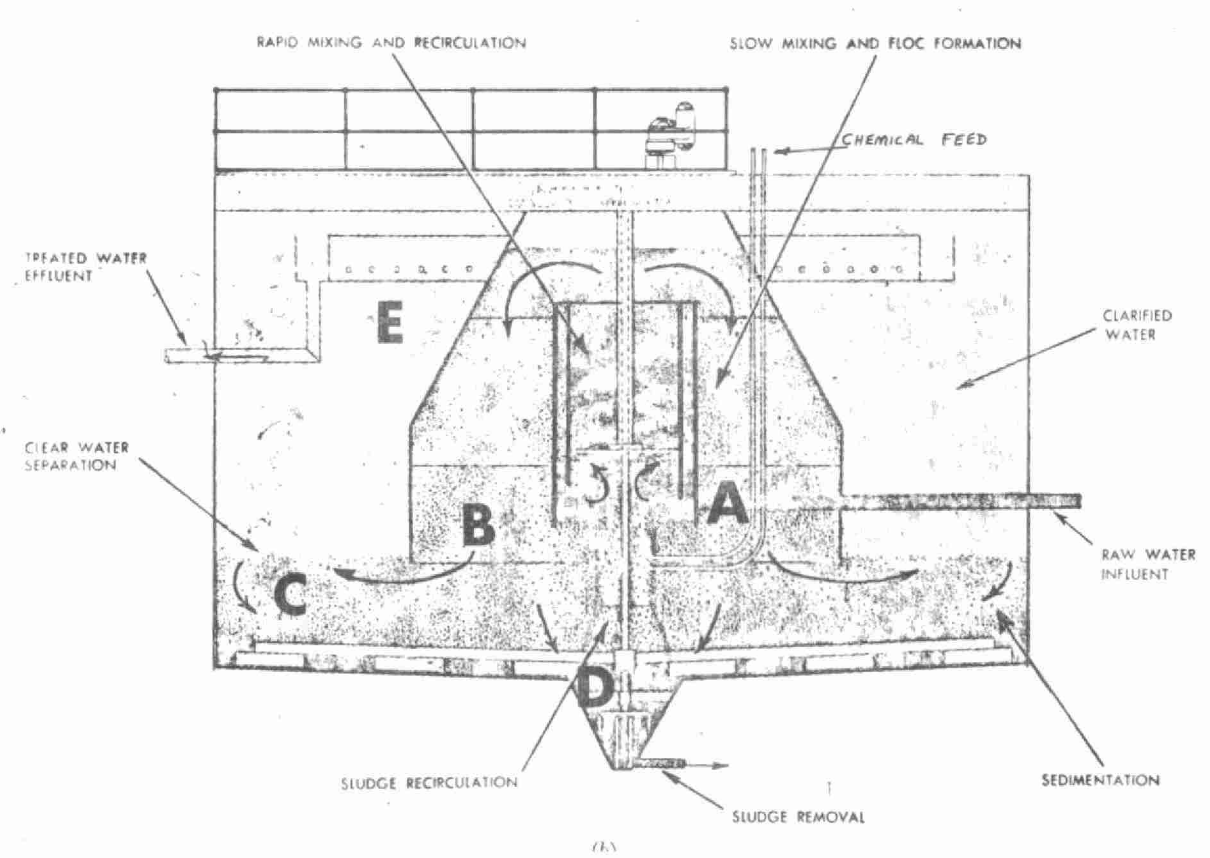
Tube Settlers

A recent development in sedimentation is installation of small, parallel tubes, called *tube settlers*, near the surface of the water in the settling basin. Tube settlers can reduce the total volume requirements of the sedimentation systems or be used with existing systems to allow an increase in the volume of water passing through. Sedimentation takes place more rapidly since the floc has only a short distance to settle.




STEEPLY INCLINED TUBE SETTLER

(Floc settles on side of tube, then slides down to the bottom where it is removed continuously.)




GRAVER "REACTIVATOR" TREATMENT PLANT

SUSPENDED SOLIDS CONTACT CLARIFIER

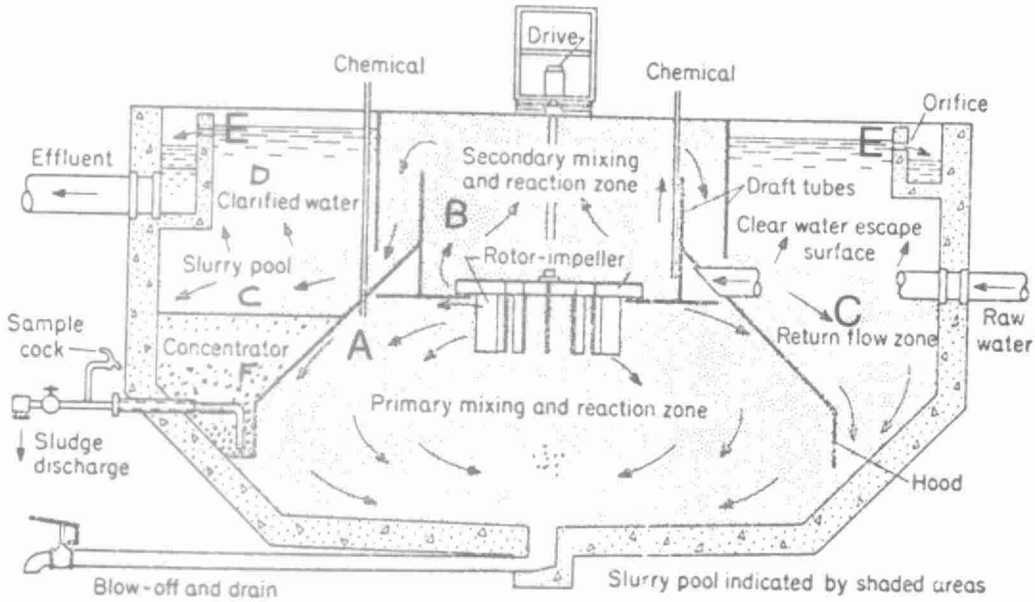
Suspended Solids Contact Clarifiers combine mixing, flocculation, clarification and sludge removal in a single unit. Many commercial types are available.

(i) GRAVER "REACTIVATOR"

After coagulation has taken place (A) the solids are mixed slowly (B) and rise into the floc blanket area (C). There, the solids are suspended between the downward force of gravity and the upward force of the rising water. Due to the constant collisions of the floc in this area, the flocs gather together until they are heavy enough to sink to the bottom of the clarifier. They are then drawn-off as sludge (D) at fixed intervals so that a constant volume of sludge remains at all times in the bottom of the clarif -.

During this time, the now clarified water rises to the overflow, and passes to the filters (E).

Suspended Solids Contact Clarifiers require less space than flocculation and sedimentation basins. They may also cost less, but they are usually not as flexible in their operation.




INFILCO "ACCELATOR" TREATMENT PLANT
(SOLIDS CONTACT UNIT)

(ii) INFILCO "ACCELATOR"

Coagulation and the first stages of flocculation take place in the primary mixing and reaction zone (A). The rotor-impeller drive pulls and pushes the floc into the secondary mixing zone (B) where the flocculation process continues. The floc rises over the up-draft tube and under the down-draft tube, and spills into the slurry pool (C). There, the floc behaves as if it had just entered a sedimentation basin. The force of gravity, as well as the force from the rotor-impeller drags the floc down. The clear water rises up into the upper regions of the clarifier (D) and spills into the overflow weirs (E). The floc, now part of the slurry pool,

is dragged back into the primary mixing zone (A) and the cycle continues. Some of the heavier floc particles settle into the concentrator(s) (F). The floc (now called sludge) is periodically drawn off from the concentrator. There is very little settling at the bottom of the primary mixing zone (A), due to the high mixing rate of the rotor-impeller.

## DETERMINING THE CORRECT COAGULANT DOSE

The following chart indicates the advantages of using the proper amount of alum.

| | Under Dose | Proper Dose | Over Dose |
|---|---|---|---|
| Turbidity Removal | Poor | Good | Fair |
| Colour Removal | Poor | Good | Fair |
| Algae Removal | Poor | Good | Fair |
| Length of Filter Runs | Medium | Long | Short |
| Residual Aluminum | High | Low | High |
| $ Value | Wasted | Good | Poor |

To learn the correct amount of coagulant to use a series of tests called *JAR TESTS* can be performed.

### Chemical Solutions

Stock solutions of coagulants, coagulant aids and other chemicals should be prepared at concentrations such that quantities suitable for use in coagulation tests can be measured accurately and conveniently.

| CHEMICAL | CONCENTRATION OF STOCK SOL. | PREPARE FRESH SOLUTION AFTER | 1 ml in 1000 ml of $H_2O$ equiv. to |
|---|---|---|---|
| Alum | 1% | 1 month | 10 ppm |
| Ferrous Sulphate | 1% | 1 week | 10 ppm |
| Activated Silica | 1% | 2 days | 10 ppm |
| Polyelectrolyte | 0.05% | 1 week | 0.5 ppm |
| Sulphuric Acid | 0.1N | 3 months | 4.9 ppm |

NOTES:

1. Alum - 1% solution can be made by adding 1 gram of powdered alum to 100 mls of water OR 1.54 mls of liquid alum to 100 mls of water.

2. Activated Silica solutions necessary for the preparation of a 1% solution can be obtained through your Ministry of the Environment regional engineer.

3. Polyelectrolyte solutions should be used with the guidance of the manufacturers.

## JAR TESTS USING COAGULANTS ONLY

Jar tests are carried out as follows: a 6-place laboratory stirrer or jar tester is needed as well as six 1500 ml beakers.

(1) Under each stirring paddle, place a 1500 ml beaker.
(2) Place into each beaker, from a graduated cylinder, exactly 1000 ml of a fresh sample of the raw water.
(3) Note on the test sheet the amount of coagulant that you are going to add to each beaker. This amount will vary from beaker to beaker.
(4) Start the stirrer and set it at maximum speed (usually 100+ rpm).
(5) Add the coagulant in increasing amounts to each successive beaker. For example, 10 mg/l to beaker #1, 20 mg/l to beaker #2, etc.

*NOTE: 1 ml of 1% solution in 1000 ml of water is 10 mg/l.*

(6) After the coagulant dosage has been added to the last beaker, continue running the stirrer at maximum speed (100+ rpm) for another minute.

(7) Reduce the speed to 30 rpm and allow the stirring to continue for 30 minutes.

(8) Note how long it takes before a floc begins to form.

(9) Note how well it withstands some stirring without breaking up.

(10) Stop the stirrer after 30 minutes. Note how long it takes for the floc to settle to the bottom of the beaker.

(11) After allowing the floc to settle for 20 minutes, note the colour and the turbidity of the *supernatant* (the liquid above the floc). This sample is obtained by using a baster.

(12) Note the chemical dosage of the best jar (the jar that has the clearest supernatant, and in which the floc settled best). This combination will tell approximately what dosage of coagulant should be applied to the process.

## JAR TESTS USING COAGULANTS PLUS FLOCCULATION AIDS

To determine if either activated silica or polyelectrolyte can help the coagulation-flocculation-sedimentation process, do the following: repeat the jar tests as before *except* this time start with the best coagulant dosage and *add* varying dosages of flocculation aid. The amount of activated silica added is usually within 10 to 20 per cent of the alum dosage used. Polyelectrolyte dosages rarely exceed 1 mg/l.

When determining the use of flocculation aids, keep one jar with alum only. Then compare the results when using only alum to the results obtained when a flocculation aid is added to the alum.

When applying jar test results to the plant, it is sometimes found that the plant operates better at a chemical dosage slightly different than that indicated by the jar tests. The jar testing is very efficient both in stirring and settling. If the plant is not as efficient as the jar tests, a higher dosage of coagulant may be needed.

*The Regional Engineer of the Ministry of the Environment should be contacted when difficulties arise either in trying to run the jar tests, or in trying to apply the jar test results to the plant.*

SUBJECT:

BASIC WATER TREATMENT OPERATION

TOPIC: 4

WATER FILTRATION

## OBJECTIVES:

Trainee will be able to:

1. Define the following: filtration, purpose of filtration;
2. Describe the filtration process;
3. Define and describe the 5 principal parts of a gravity filter;
4. Define and describe the 3 operating items to be checked for optimum capacity and maximum efficiency;
5. Describe what is meant by
   (a) filtration rates
   (b) backwashing
   (c) washing with air
   (d) water scour;
6. Define and describe the operating problems of a filter;
7. Describe how to do a "probe" check;
8. Describe how to check the "actual loss of head" across a filter;
9. Describe how to check the "actual rate of flow" through a filter;
10. Describe pressure filter operation;
11. Describe the operation of a diatomaceous earth filter.

# WATER FILTRATION

## GENERAL CONSIDERATIONS

Most of the potable and industrial water supply in Ontario comes from surface water-lakes, rivers and streams. The pollution in surface waters requires adequate treatment to make them safe to use. A water purification plant not only produces a safe water but also provides water which has no objectionable taste, odour or colour.

This may be accomplished by:

1. treating the "raw" water entering the plant with various chemicals,
2. mechanically agitating it for proper mixing and coagulation of the chemicals for flocculation and
3. allowing enough retention time in the plant to settle out most of the suspended matter.

The next and most important phase through which it passes is - *FILTRATION*.

Filtration is the process of removing turbidity (suspended particulate matter) from water by passing it through some porous filter media such as sand, anthrafilt or a combination of both.

## THE "SLOW" SAND FILTER

Filtration, as we know it today, began in about 1830 when the first of the so-called "slow" sand filters was constructed and put into use in London, England. These units operated at rated of flow of from 2 to 10 USMGD per acre (equivalent to 0.032 to 0.160 US gpm per sq. ft. or 1/10 gal./sq. ft./min). The "slow" sand filter is fast disappearing mainly because of the high cost of labour required to operate this type of unit, and the amount of land required.

The "slow" sand filter consisted of an underdrain system with a gravel bed over it. On top of this was spread the filter sand. The water flowed in on top of the sand and filtered down

through it, depositing the turbidity in the upper layers of the sand. During its passage through the sand layer the bacteria already present in the filter attacked and in most cases, destroyed any harmful bacteria present. The water was purified by this method rather than by chlorination. In fact this was the only method of disinfection which was practiced at that time. Once the rate of flow became too slow for any further operation, the water was shut off, the unit drained, and the top layer of sand removed. Then the unit was ready for another run. The cost of removing the sand by hand and replacing it regularly was considerable.

## THE "RAPID" SAND FILTER

The "slow" sand filter evolved into the "rapid" sand filter which is in use today. The "rapid" sand filter can either be of the gravity or the pressure type. In either case, the water passes downward through the bed of sand at rates of flow from 2 to 3 US gpm per sq. ft. Because of a much higher rate of flow, the water must be pretreated by coagulation and settling to remove the greatest part of the suspended matter before the actual filtration process. At this higher rate relatively little purification took place by the bacterial method and in its place chlorination was practiced for disinfection. Unlike the "slow" sand filter, the "rapid" sand filter can be cleaned of the accumulated turbidity by reversing the direction of the flow of the water. This process is called *backwashing*. In backwashing, the flow of water through the sand expands and scours the bed and carries away, in the water stream to the sewer, the accumulated solids.

The media used in the "rapid" filter today, include *sand, anthrafilt*, and in some cases, a combination called *mixed media*.

## PURPOSE OF FILTRATION

The primary purpose of filtration is to protect public health. In the earlier days of filtration, this was the only purpose in treating the water. Today, however, this is no longer

true. The tremendous growth in cities and industry made it necessary to remove any objectionable odours, tastes and colour as well as providing an absolutely clear finished product.

## FILTRATION PROCESS

Laboratory test results and observation have shown that the filtration process removes almost all kinds of turbidity from the water supply. This is accomplished by the following: (a) Mechanical Straining, (b) Impingement, (c) Electrolytic Action and (d) Chemical Reactions.

(a) Mechanical Straining

The largest particles remain on top of the filter because their size will not allow them to pass through the small space between the individual grains of media.

(b) Impingement

Do you remember as a small boy sailing match sticks in the gutter on a rainy day? Remember how the match sticks tended to float to the side of the stream and stick to the curbing? Did you ever wonder why it is that when you drive your car through mud in the pouring rain, that the mud splashed onto your car instead of washing off with the rain? The action taking place in either case is the same when turbid water passed down through the sand grains in a filter. A natural attraction causes the particle to move to the surface of the media and stick to it.

(c) Electrolytic

Both sand and anthrafilt grains carry an electrical charge as do particles of turbidity which are suspended in the water. These electrical charges change the physical and chemical makeup of the constituents, affecting their ability to filter.

(d) Chemical Reactions

There are many organisms in the top layer of the filter media. These organisms will promote chemical reactions with incoming turbidity and other organisms, affecting the filtering action.

## CONSTRUCTION OF A SAND OR ANTHRAFILT FILTER

A gravity filter is essentially a concrete box. Its length, width and depth are determined to suit the configuration of the building, and the rate of flow which is desired. The depth of the box is determined by the amount of *head* or pressure required and also by the type of underdrain which is used.

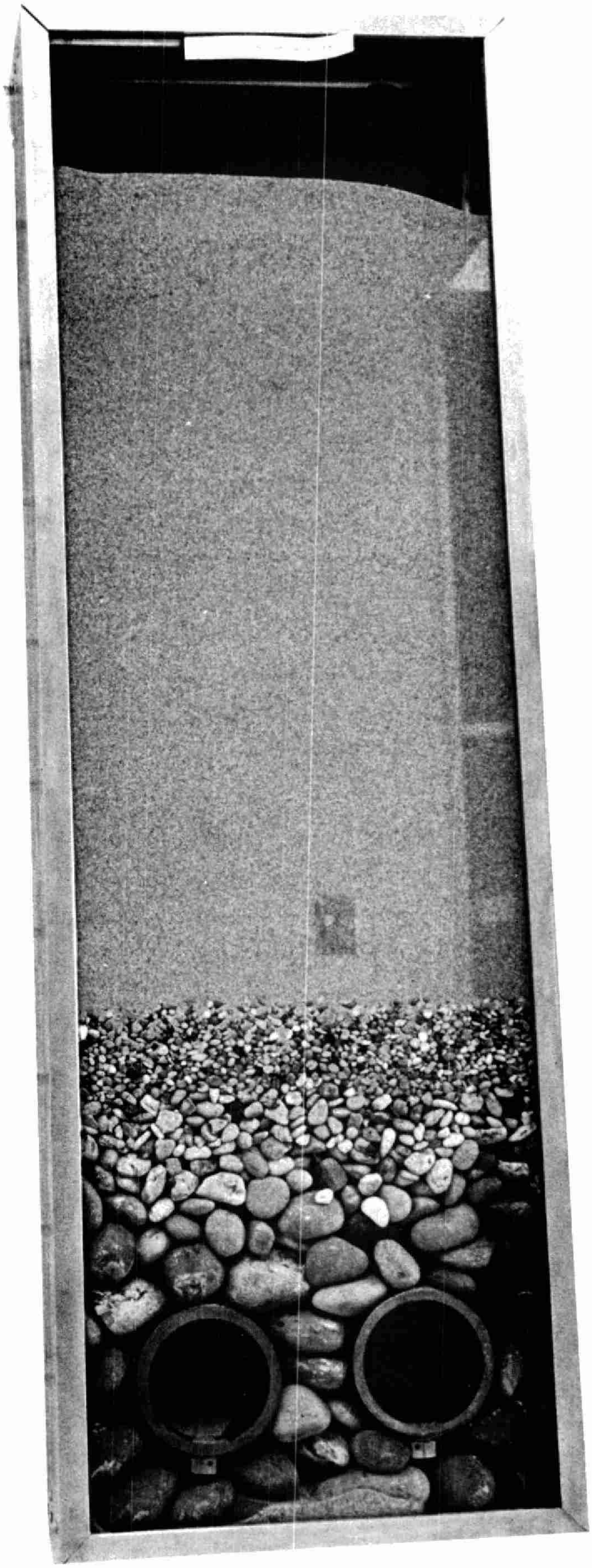
The principal parts which make up a gravity filter are shown in Fig. 4-1 and include (a) the *underdrain system*, (b) the *gravel subfill*, (c) the *filter media*, (d) the *surface washer* and (e) the *wash troughs*.

(a) Underdrain System

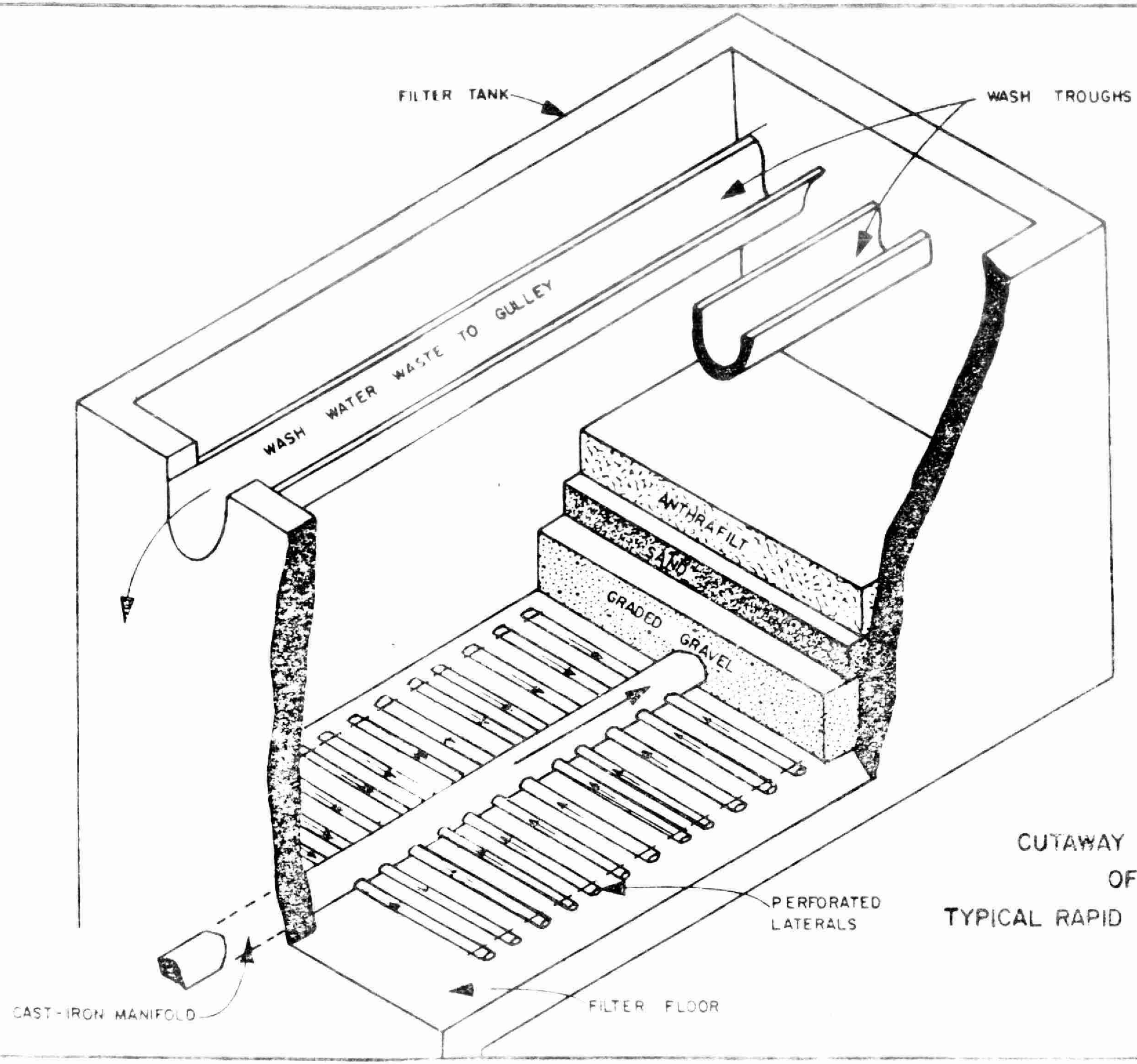
The underdrain system distributes water evenly over the entire area of the filter. The most common type of underdrain is the header, lateral type, shown in Figure 4-1. In the latest designs, the laterals are thin-walled, stainless steel pipe. Holes are located on the underside of the laterals, properly sized to handle the water flows required for adequate distribution at all times. The backwash flow rate of the average filter is 12 to 15 gallons per sq. ft. per minute and the operating rate only about 4 gallons per sq. ft. per minute. Since the only head available during the filtration process is the depth of water in the filter, the holes are normally sized to handle the filter flow. Adequate distribution is ensured at the higher flows encountered in backwash when sample pressure is available from the backwash pump, or washwater tank.

(b) Gravel Subfill

The subfill performs two primary functions. (1) It keeps the bed of the filter media, which is extremely fine, from passing out through the holes in the underdrain system. (2) It distributes evenly the flow of water coming from each of the holes in the underdrain system. Thus an even flow passes either up or down through the bed of filter media. (The depth of gravel required in any design of filters is directly related to the distance between the holes in the



Cross Section of Sand Filter




CUTAWAY VIEW
OF
TYPICAL RAPID SAND FILTER

NOT TO SCALE

underdrain system. The gravel depth should be from 2 to 2½ times the distance between the holes in the underdrain system. For example, if the holes in the underdrain are on 6-inch centres, the gravel depth should be 12 to 15 inches.)

Different layers, or size, of gravel make up the required depth. The bottom, or first layer, of gravel is related to the size of the openings in the underdrains, which vary from ½" through to 2". The holes in the underdrain vary from ¼ to 3/4 of an inch wide. Progressively finer grades of gravel are spread on top of the coarse gravel; the minimum depth of a layer is 2" and the final layer of gravel, or "torpedo sand" as it is sometimes called, will support the actual filter media.

The function of the gravel is to provide distribution of the water, so the particles must be as round as possible and insoluble. The most common material used is silica seagravel. Large deposits of this material are imported from the Atlantic coast. Anthracite coal or anthrafilt, as it is normally called, is also used as a supporting media. Unlike gravel, anthrafilt is not round, but it will not pack and will remain open, allowing the water to pass up and down freely through it. Such things as crushed limestone cannot be used because it will pack down into a solid, impervious layer (as it does on roadways), and slowly, but surely, dissolve in the water.

(c) <u>Filter Media</u>

The actual filter media is on top of the bed of gravel and is usually from 27" to 30" deep. The original media used was sand. Later, anthracite coal or anthrafilt was used. Today, with the coming of the multi-media systems, garnet and other types of sand are found. These materials incorporate in the grain structure, such things as carbon, which greatly reduce their weight.

Two terms are used which define the size of the filter media. The first is called the Effective Size and is described as the "theoretical size of a sieve in millimetres which will pass 10 percent of the media". The second factor is called the Uniformity Coefficient. It is described as:

$$\frac{\text{theoretical size of a sieve in millimetres that will pass 60 percent}}{\text{theoretical size of a sieve in millimetres that will pass 10 percent}}$$

A perfect filter media, numerically speaking, has a uniformity coefficient of 1; however, in practice it is seldom below 1.3 and good filter media should never exceed 1.7. The effective sizes of the media range anywhere from .18 to 1.7 depending on the media and its location.

Effective size of the filter media will range from 0.15 for garnet to 1.0 ml for the coarser grades of anthrafilt.

Anthrafilt is a special type of anthracite hard coal which has been crushed (screened) for size and graded to have a uniform density. Anthrafilt has a lower specific gravity (1.5) than sand (2.65), so a lower velocity is required when backwashing the filter.

Anthrafilt is lighter in weight (55 lbs. per cu. ft.) than sand (100 lbs. per cu. ft.), but is much more expensive.

In order to benefit from both of these media, they are generally used together. They can be readily backwashed together and will always remain separated due to the difference in their backwash characteristics. If the sand grain size is made too fine, it will begin to mix with the anthrafilt and if the anthrafilt grain size is made too coarse, then it will mix with the sand. The coarse anthrafilt on top gives the filter a larger

capacity for turbidity removal, while the lower layer of fine sand provides for maximum particle removal. The combination of the two provides a media that will give a greater number of gallons per filter run with a better quality of water.

(d) <u>Surface Washer</u>
The surface wash equipment is positioned directly above the top surface of the filter media. It may be (1) a fixed grid of pipes with nozzles, (2) a rotating tubular arm with small jets all along the trailing side or (3) a grid which introduces compressed air into the filter media as an air wash. Any of the three methods can be used to remove any and all suspended matter from the filter media.

(e) <u>Wash Water Troughs</u>
The wash water troughs are located above the surface wash equipment. They are installed high enough above the bed to provide a free space between the underside of the trough and the top of the bed equal to half the bed depth. This is the backwash space normally provided for the filter media to expand into for adequate cleaning. The minimum required backwashing space is 30 percent. The depth of the wash troughs varies with the amount they can hold so the distance from the top of the wash trough to the top of the bed will range widely.

(f) <u>Other necessary accessories</u> include the influent, effluent and wash water valves, and a valve to control the flow of water to the surface wash equipment. All of these valves are controlled from a console, located in front of and facing the filter. Built into the control console are gauges showing loss of head, rate of flow through the filter, and backwash rate of flow.

In some older plants, especially the smaller ones, individual hand valves are still in use. The large, newer plants feed data such as filter flow rate and loss of head into master control consoles which automate the valve operations required to backwash a filter and return it to service.

## FILTER INSTRUMENTATION

To operate a filter at its full capacity and highest efficiency, the status of the filter is checked continuously and the (1) *turbidity* (before and after filtration), (2) *loss of head*, and (3) *rate of flow*, are recorded.

(1) Turbidity

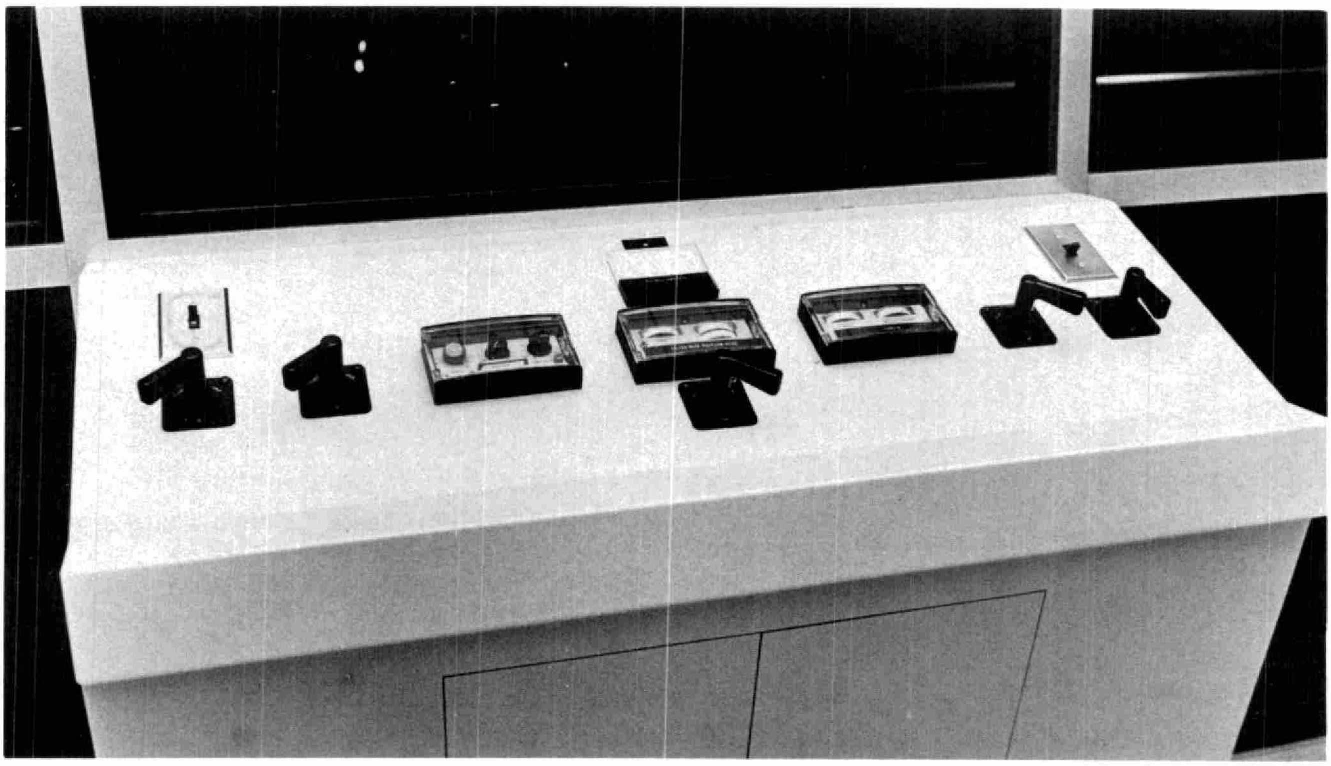
The prime function of a filter is to protect the public health by removing disease producing organisms from the water. Most of these organisms are bound up in the coagulated floc particles entering the filter. The turbidity remaining in the filter effluent is the best indicator of filter performance. Turbidities can be measured in the laboratory by such instruments as the "Hellige" turbidimeter, and can be monitored on the filters with indicating and/or recording type instruments such as those produced by Keen and by Hach manufacturers.

(2) Loss of Head

A filter was earlier described as a concrete box with an underdrain gravel subfill and filter medium; the box, of course, is filled with water. In most filters, the distance from the surface of the water to the centre of the underdrain system is approximately 10 feet. This is the total head or pressure available to push water through the filter. When the filter has just been backwashed, it is in its cleanest state and offers the least resistance to flow through it. This is called the smallest or lowest loss of head of the filter and is usually less than 2 feet. The maximum head available during the filter run is the difference between the total depth and the initial loss, leaving an available head in most filters of about 8 feet (10 feet - 2 feet).

When in operation, the filter removes the turbidity from the water. As the turbidity accumulates in the bed, the resistance to the flow of water increases; in other words, the head loss through the filter increases.

Filter Control Gallery



Filter Control Console

Therefore, the reading of the loss-of-head gauge is an indication of the "cleanliness" or the "dirtiness" of the filter. The loss-of-head gauge indicates when the filter needs backwashing. A simple loss-of-head gauge can be constructed by connecting a clear piece of plastic tubing to the underdrain header, and running the tubing up the side of the filter box so that the open end of the tubing is above the surface of the water in the filter. Mark the level of the surface water in the filter on the wall next to the tubing. Then, at any time, the distance from this point down to the liquid level in the tube can be measured -- this distance (in feet) is the head loss. Most modern loss-of-head instruments operate on this principle and simply transmit the measurement (or distance) to the instrument located on the control panel.

(3) Rate of Flow

There is a change in pressure loss through a gravity filter during the period of the run. If there is a variation in the pressure loss across the filter and the total amount of head available in the filter is constant, the rate of flow through the filter will vary with the pressure. This does not lead to the best operating results, so a rate of flow controller was developed to overcome this changing pressure and make the filter operate at a constant rate of flow. The rate of flow controller consists of a valve and a primary measuring device (in most cases a venturi tube), which allow the water to flow from the filter at a constant but adjustable rate, independent of the change of pressure loss or loss of head within the filter proper.

The venturi tube is designed to measure two pressures and the difference in the two pressures will vary with the rate of flow. These two pressures are applied to the controlling diaphragm of a valve so that as the rate of flow through the tube decreases, the valve opens. This way a constant flow is maintained.

## FILTER OPERATION

### Pre-Treatment

*The most important thing to remember about the water arriving at the filter(s) is to condition and pretreat it thoroughly before it ever gets there.* Without this pretreatment, (or if the pretreatment carried out is not enough) the operating efficiency of the filter(s) is going to be drastically reduced. Filter runs will be cut short, resulting in a considerable increase in backwashing and the amount of wash water used. Consequently, plant output will be reduced because filters have to be washed with filtered water. The filter beds will become overloaded with algae and particulate matter, and mud balls will very likely develop.

*The type of conditioning applied to the raw water depends on the quality of the raw water entering the plant.* The demand on water treatment plants, however, is continually increasing. If a given chemical treatment produces a good floc, coagulates well, and results in a water passing over the filters with, for example, 1.0 mg/l of turbidity at a flow rate of 25 MGD, an increase in flow rate to 40 MGD will not produce the same quality water over the filters even if the chemical dosage is increased in proportion to the increase in flow. This is because increasing the flow rate by 60% will allow less time for the floc to settle out. This results in a greater "carry-over" to the filters, causing shorter filter runs.

### Filtration Rates

Until a few years ago, the normal design filter rate for a rapid sand filter producing potable water, was two gallons per minute per sq. ft. of filter bed area. Since then investigations of filter aids have been carried out, using dual and multi media. As a result, operating filter rates can be notably increased. It is common today to find filters operating at rates of 5 gal. per minute per sq. ft. of filter bed area. These newly designed filters use a media in which the particle size is greatest at the top. By using various types of filter media, the particle size gets progressively finer, down through

the bed to the bottom. Since the voids (or spaces) between the particles will be larger where the particle size is greatest, the voids in the upper portion of the bed are at their maximum. These provide a great storage area for turbidity particles. As the water proceeds through the bed, the size of these voids becomes progressively smaller due to the accumulation of turbidity particles. At the same time, the storage for the turbidity is becoming less, but the degree of filtration is becoming better.

It is common today to have up to five different layers of material in a filter bed. The multi-layered filter is a part of the micro-floc process. In other types of media, two layers are used, generally sand and anthrafilt: two-layer filters are commonly known as dual media filters. Choosing the type of process to be used can only be done after a thorough study of the treatment process and raw water conditions.

It is not always possible to increase the rate through any particular filter. Filters are normally designed for specific rates of flow, and such things as the inlet flumes, the underdrain system, rate of flow controllers, and the discharge piping are all sized for this flow. For example, to double the rate of flow, the total head available in the filter may be sufficient to maintain this increase in flow rate. In many plants, it is possible to have two different rates of flow at different times of the year. This is particularly true when treating waters that are difficult to coagulate. The rate of flow through the plant may be reduced during the winter months, in order to compensate for the poor quality of water being fed to the filters, or alternately, accept the poorer water quality.

The conventional rapid sand filter uses one grade of sand (0.45-0.55 mm and a S.G. of 2.65) approximately 30 inches thick underlaid by graded layers of gravel as supporting media. Normally under these conditions, the actual entrapment of suspended matter is restricted to the top two inches of the sand bed. The remaining 28 inches of sand act as insurance against a serious turbidity *breakthrough*, which means the turbidity on the filter has increased to the point where it is being carried through by the water being filtered.

The storing capacity for suspended matter in the conventional rapid sand filter is considerably less than in a dual-media filter where the top 18 inches of the sand bed have been replaced with a coarser and lighter media, anthrafilt (0.8-1.2 mm and a S.G. of 1.75). Under ideal conditions, the entire 18-inch depth of anthrafilt plus 1-2 inches of sand, is available for the storage of suspended matter. This means that the head loss, instead of being concentrated in the top 2 inches in the conventional sand bed, is distributed through a depth of 18-20 inches in the dual-media bed. This makes it possible to use higher filter rates for longer filter runs. Under these conditions, however, it is normal practice to apply a small dosage of polyelectrolyte to the water just before it reaches the filter. This is in addition to the alum, which is applied as a part of the pre-treatment process.

Since the dual-media bed has a good deal of storage capacity in the anthrafilt layer, it should be possible to use the anthrafilt layer instead of a sedimentation or settling tank, if the turbidity in the raw water is relatively low (say less than 15 mg/l on the average and maximum turbidity levels of 50 mg/l). Of course, the water should not have any taste or odour problems and the algae concentrations should be low.

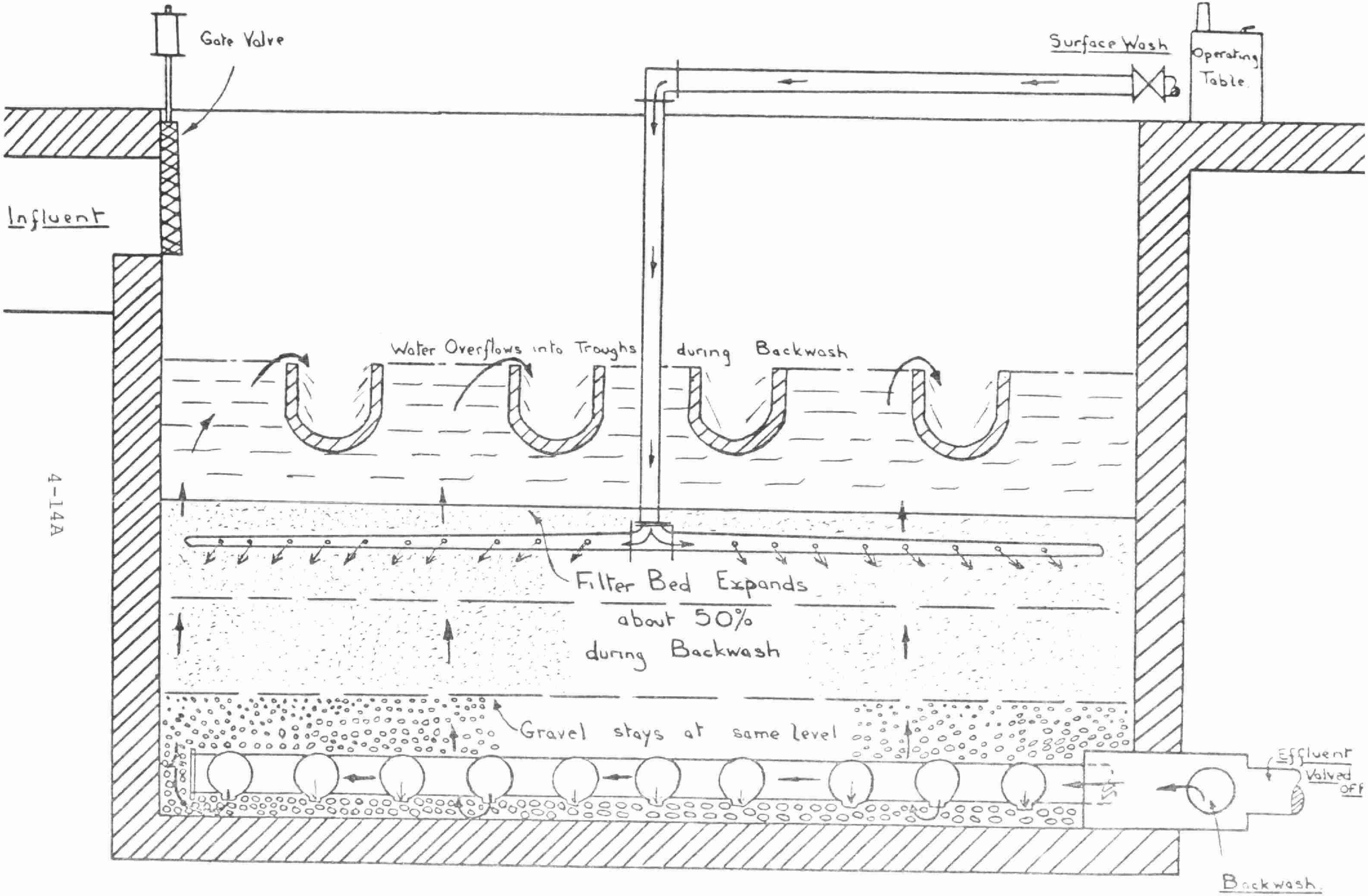
## Backwashing

*Backwashing a filter is the exact opposite to filtration.* When backwashing, the water rises up through the filter rather than passing down through it. The backwashing process removes the accumulated turbidity from the filter rather than collect it. Municipal filtration plants always utilize treated water for backwashing. The water is delivered to the filter either from an elevated tower or via a backwash pump (from the clearwell). Either method provides the necessary pressure and volume for carrying out the back wash process.

A normal rate of flow during the backwash cycle for conventional filters is 15 gal. per minute per sq. ft. of filter bed area. These figures will vary depending on the temperature of the water used to backwash. As the temperature increases,

Filter backwash at maximum rate

Low rate at end of backwash




BACKWASHING A FILTER.

N.T.S.

the backwash rate is increased to give the same amount of expansion to the filter bed. The backwash water enters through the underdrain head by the holes of the underdrain system. Rising up through the gravel bed, it enters the filter media. The gravel bed further distributes the water uniformly throughout the entire filter. It is extremely important to note *that in the operation of any filter, all valves be opened or closed slowly.* As this valve is opened, the amount of water rising up through the filter media gradually increases and as more and more water is forced up through the sand bed, the pressure on the underside of the individual grains of filter media becomes greater. This pressure eventually overcomes the weight of the particle of filter media and the point at which this occurs is known as *the point of fluidity.* Once the flow reaches this point, the particle will rise and the filter bed will start expanding. The normal expansion of the filter bed is 30 to 50 per cent during the backwash period. Backwash space must be provided in the filter to permit this expansion during the washing period. This is why the wash trough must be at a fixed height above the filter bed. The particles of media roll around in the bed, continuously rising and falling. In the process, they rub against each other. The combined action of the water moving past the particle of media and the scrubbing action of the particles rubbing against each other removes the accumulated turbidity from the filter media grains.

It was found from experience that this does not always remove all of the turbidity from the filter media, and that over the years, turbidity will accumulate on the media grains, limiting their effectiveness as a filter media.

To overcome the turbidity build-up on the filter grains, various types of surface wash systems are used. These systems consist of water jets aimed down on the grains of filter media and physically aid in removing the layer of accumulated turbidity. The most common unit in service today is the Palmer filter bed agitator. This unit is installed directly above the bed and is a self-propelled revolving agitator incorporating high velocity

nozzles or jets. The jets are inclined to discharge at an angle down into the filter bed. The jet of water helps clean the filter media and also propels the arm, causing the entire assembly to rotate. It is most important to use the minimum water pressure designed for these units. Without enough pressure, they are ineffective.

When in use, the filter media are backwashed at the point of fluidity. The flow is about 6 gpm/sq. ft. This is the point at which the particles of media are in effect "weightless" in the filter bed. The Palmer agitator is then turned on and allowed to run for a period of 5 to 7 minutes. The force of the jets of water from the agitator cleans the grains of the filter media and moves them so that the entire bed is gradually turned over and exposed to the jet action. Following this, the backwash rate is gradually increased and the agitator turned off. The filter is backwashed at its normal backwash rate for an additional 3 to 5 minutes, and continued as long as necessary to remove all accumulated turbidity. The water is then slowly turned off and the media allowed to settle.

*Always use the amount of backwash water required to clean the filter.* It is very important that sufficiently high expansion of the filter be used. *WHY?* To ensure that the rise rate (or speed of the water rising up in the filters) is sufficient to carry the particles of turbidity out of the filter and into the wash trough. While lower rates of flow in many cases seem to do the job, there are no savings if all the turbidity is not removed.

## AIR WASH FILTER

The air wash filter operates on the following principle:

### Washing With Water and Air Scour

In this system, a return flow of water slowly comes up from below through the mass of sand. This keeps the sand from expanding. At the same time, air is evenly distributed up through the sand causing considerable turbulence in it.

If the filter is washed and closely examined, it will be found that the sand is not really stirred up. The sand mass remains more or less in place. It has been, however, subjected to a vibration caused by the passage of a large number of air bubbles. The vibration removes the impurities and carries them off with the wash water. Because there are no eddie currents created in the sand mass, the impurities can never descend to the lower part to form mud balls.

Furthermore, the gravel support layers are unnecessary and should be omitted or reduced to a small layer of coarse gravel to prevent it from mixing with the filter mass by the energetic action of the injected air.

This washing system allows a larger grain size to be used. There is no longer a need for surface washing and sand expansion indicators. The washwater rate can be determined as required and washing operations are carried out without supervision. This facilitates automatic operation.

## OPERATING PROBLEMS OF A FILTER

The operating problems of a filter can be divided into two categories:

1. mechanical failure of controls and equipment
2. failure of the filter itself.

When seeking the causes of filter bed failure, look for:

1. *Clogging* the filter media by turbidity accumulation. This is caused by incomplete removal during the backwash operation.

2. *"Cracking"* or contraction of the bed. This results from too long a filter run. The filter media gets too dirty and can pull away from the filter wall. This allows untreated water to penetrate to the lowest layers of the filter bed.

3. *Mud Balls* - Tiny balls of accumulated turbidity bind together with particles of filter media. As these mud balls increase in size, they become heavier than the filter media and will gradually sink down to collect on the top layer of gravel.

4. The *shifting and intermixing* of the gravel layers - this problem occurs primarily in the fine gravels located in the top of the supporting bed. It is caused by uneven backwashing, rapid change in flow rate, a clog or break in the underdrain system.

Operating Problems: How to Correct Them

In some cases, the problems are not necessarily due to the operation of the filter itself. *Filter clogging*, for example, is frequently caused by inadequate pretreatment. Clogging can often be overcome by pre-chlorination to limit bacterial growth in the media.

*Cracking* or *contraction* generally results from either inadequate backwashing or over-running the filters. Loss of head is one indicator as to when backwash is required; the other is the amount of turbidity in the effluent.

Adequate backwashing in every filter operation is extremely important. *The backwash flow rate should be as high as possible without losing filter media.* The backwash should be carried on until the filter media is cleaned. Samples of sand should be taken periodically, at every 6" down through the top 18" of the bed. The amount of turbidity still left in the sample indicates the condition of the media. No media will ever be absolutely clean, regardless of the extent of the backwash.

Filter Controls and Equipment Maintenance

There are many and varied types of equipment to be maintained in connection with filters. These include: hydraulically or pneumatically operated gate valves, butterfly valves, sluice gates, rate of flow controllers, surface wash equipment, instruments for filter operation (such as loss of head and rate of flow gauges, as well as the gauges used for indicating and recording the wash rates). Good maintenance to be effective and efficient, must be based on anticipating troubles as well as keeping up with the routine maintenance.

Records and Maintenance

If you have a full and complete record of past troubles and breakdowns, including the repairs necessitated, a periodic review of such records will alert you to possible future trouble spots. Also, keep enough spare parts on hand to limit any downtime resulting from a breakdown of equipment and have the proper facilities and tools for repairs.

The *operating cylinders* on the various *valves* (influent, effluent, wash, and waste) need periodic checking to replace the gland packing and occasionally to replace the cup leathers on the piston.

Replace rounds of packing in the cylinder packing or stuffing boxes with the proper grade for the particular service. Grease each round of packing liberally with a pump grease. "Stagger" the split ends of the packing radially on the valve stem and make sure that the glands are pulled down evenly but not too tightly. (A "cocked" gland can exert tremendous friction load on the valve stem.)

To remove a cylinder from a valve when replacing the cup leathers, bolt a blank wooden flange faced with rubber gasket on one end of the cylinder, and fill the cylinder with a strong solution of muriatic acid and hot water. This cleans the plating of calcium bicarbonate from the brass liner of the cylinder and leaves the bore smooth. If, after some years of operation, one end of the cylinder liner is scored, invert the cylinder when replacing it. Usually more scoring is found on the bottom of the cylinder liner.

The *surface wash equipment* requires little maintenance except for occasional cleaning of the jets on the agitator arms. If the filter media is anthrafilt some fine grains may become lodged in the jets but it is a simple matter to unscrew these for cleaning. *Even though this is a minor maintenance chore, it should be done periodically, because the agitator arms will not perform effectively if a number of jets become clogged.* The ball bearings on which the agitator arms rotate give very little trouble and so do not require special attention.

The maintenance of the filter bed itself involves a periodic *"probe" check* of the media to determine the contours of the pea gravel layer (see Figure 4-4). This should be done twice a year.

*To do a "probe" check,* sketch an outline of the filter area. Drain the water from the filter to be checked. Walk along the wash troughs and thrust a six or seven foot length of steel rod down through the filter media until you feel the bottom of the rod come into contact with the pea gravel. Check a marker near the top of the rod against the lip of the wash trough to determine the depth of the gravel at that point. Enter the reading obtained by the "probe" at the appropriate point on the sketch of the filter area. Repeat over the whole bed to obtain an accurate picture of the gravel contour. If undue "humping" of gravel is found in any part of the filter, the sand and anthrafilt must be removed from the area and the pea gravel re-graded and levelled.

## Instrument Checking and Maintenance

The filter console gauges are usually for *loss of head* and *rate of flow*. These instruments will provide continuous accurate readings only if they are given periodic calibration checks and maintained in good condition. No matter how sophisticated the instrumentation, do the following to determine their accuracy:

(1) *To check the actual loss of head* through any filter, obtain a length of polyethylene tubing, ½" or 3/8" diameter, pass one end down to the pipe gallery floor from the filter console above, connect the tubing to a centre tap on the filter effluent line and open the tap allowing water to rise in tubing. The distance from the level of the water in the filter to the level of the water in the tube is the actual loss of head across the filter at that particular moment. If the indication on the filter gauge console does not agree with this value (plus or minus the allowable tolerance) the gauge reading is incorrect. Maintenance is required to correct the situation.

(2) *To check the actual rate of flow* through the filter, use a "Hook Gauge". It is very accurate. A "Hook Gauge" consists mainly of a supporting member (1/8" x 1" scrap iron or similar) about 48" long to which are fastened two small brackets (see Figure 4-5). On each bracket is positioned a ½" x 1-1 ½" brass machine screw which has been ground to a needlepoint at one end. The pointed ends of the brass screws are held in the vertical position by the small brackets and lock nuts. These two "points" on the hook gauge can be positioned so that the distance between points is exactly six inches or 1 foot (whichever is preferred). A stop watch is used with the hook gauge. In use, the top end of the scrap iron is bent at right angles and the gauge is lowered into the filter, between any two wash troughs. To check the actual filter rate, close the filter influent valve leaving the effluent valve open. Watch the water dropping in the filter and when the water just "breaks" the top point of your gauge, start the stop watch. Stop the watch exactly at the point where the dropping water just "breaks" the bottom "point" of the gauge. The time taken for the filter to pass either 6" or one foot of water in a given period is determined accurately. Knowing the filter area, the rate can be calculated in millions of gallons per day (MGD), which is indicated on the console instrument. A very accurate check is obtained on another aspect of the filter, because a given volume of water passing through the filter in a given time is measured and determined. Allowances must be made for the space occupied within the filter by such accessories as wash water troughs and gully walls, and whether the time is checked with the water level above the troughs or below them.

<u>Pressure Filters</u> (see Figure 4-6)

There is relatively little difference in the design of gravity and pressure filters as far as the internal components are

concerned. There is one very large difference in their *operation*, however: a gravity filter only has a pressure of approximately 8 feet of water on it; the pressure across the bed of a normal pressure filter can be as high as 60-70 psi. It is therefore possible to "drive" or "push" the water through these filters under any operating condition in which the filter might be found.

Since it generally is not feasible to provide very large vessels equivalent to the flocculation and sedimentation of a conventional plant, it becomes quite difficult to provide adequate settling, and then move the water from the effluent of the settling basin into the filter. This normally requires pumping but the pumping process will break up the floc particles and make any more filtration difficult. The in-line application of a coagulant such as alum is generally not satisfactory, and lends itself to only a very limited number of water sources to be treated. Coagulant aids (polyelectrolytes) are a great help when applied to pressure filters, as they can be used for in-line application and for the rapid formation of a floc.

Since the sand bed cannot be seen during the backwash period, the best procedure is to provide a sample stream which can be examined continuously during backwash, and ensure that the rate of flow will not backwash the filter media out of the unit. From time to time, however, it is necessary to increase the backwash rate to a point where a small amount of media is being lost. This determines that the unit is being backwashed at the maximum possible rate. All these difficulties can be overcome through the installation of proper controls, so pressure filters of either the vertical or the horizontal type can be used to good advantage in small installations where gravity filters are too costly. The difficulty of providing adequate pre-treatment however, unfortunately limits the application of pressure filters in the water treatment field.

## Diatomaceous Earth Filters

Diatomaceous earth filters can be described as filters in which the filtering media is discarded along with the accumulated turbidity. There are a few diatomaceous earth filters installed

in the Province for the treatment of water. These filters are limited to those waters which have very little turbidity. In all cases algae are considered turbidity, even in waters that are relatively free of colour. For waters that fall into this category, diatomaceous earth is a quite suitable method of treatment to remove suspended matter economically. The filters themselves are either of the pressure or the vacuum type; in either case, the water is clarified by passing it through the diatomaceous earth. Diatomaceous earth is held on a fine mesh fabric or screen (called septum) by the pressure of the water passing through it. Diatomaceous earth removes the turbidity from the water by filtration. Turbidity accumulates in the coating or "cake".

Diatomaceous earth is a natural occurring material composed of the fossilized skelton remains of microscopic algae known as diatoms. Each tiny diatom is a very porous structure of almost pure silica and therefore makes an ideal filter media. In the operation of the filter, a small amount of the earth is circulated through the filter and accumulated on the septum, building up a thick cake known as a pre-coat. The raw water is then fed to the filter. A small amount of additional diatomaceous earth is mixed with the water. This added portion is known as the body feed. There is a continuous accumulation on the septum consisting of a mixture of turbidity and diatomaceous earth. Since diatomaceous earth is by nature porous, the rate of pressure build-up can be controlled by varying the amount of body feed as required. The limit of filtration is governed by the pressure loss across the filter; a pressure loss of 30 psi across the filter is not uncommon in pressurized systems. When the maximum allowable pressure has been reached, the direction of water flow is reversed and the accumulated diatomaceous earth and turbidity is flushed to the drain. A new precoat is installed on the septum and the filter is ready for a new cycle. Like the pressure filter, this type of system has only proved competitive from a cost standpoint on the small systems.

## Direct Filtration

Although we have been discussing filters that operate on water treated by coagulation and sedimentation, in some installations this is neither necessary nor practical. In many locations, the turbidity of the water and the corresponding coagulant dosage are sufficiently low that the filters can be operated without sedimentation. The alum is applied to the water through a mixer, followed by 10 to 15 minutes of flocculation. All the turbidity, plus the coagulant which has been added, is applied directly to the filter. This is done to filters which contain either dual or mixed media, because only this type of filter media has enough room to store the large amounts of solids applied to the filter and still get reasonably long runs. This type of filter is generally limited to those waters whose maximum turbidity will not exceed 40 JTU and whose average turbidities are down in the range of 5 to 12 JTU. Either gravity or pressure filters can be used and function equally well.

**SUBJECT:**

BASIC WATER
TREATMENT OPERATION

**TOPIC: 5**

EQUIPMENT MAINTENANCE
SYSTEM

## OBJECTIVES:

Trainee will be able to:

1. List the components that a good maintenance programme requires.

2. List the diagrams essential to proper maintenance of equipment; explain what these diagrams should show and know how each part or piece of equipment functions within the process.

3. Outline the usefulness of a data card.

4. Determine the frequency of inspection.

5. Outline the frequency maintenance card system.

6. State why it is necessary to note checks on the frequency cards.

7. Determine the checks and preventive maintenance to be done at any time.

8. Give an example of frequency control.

9. State why a master schedule and board are necessary.

10. Name 4 predictive tests.

11. State what should be recorded in a log book.

12. Name 4 pieces of information which can be obtained from a log book.

# EQUIPMENT MAINTENANCE SYSTEM

The public demands and expects high quality water and sewage services which operate without interruption. To achieve this objective, the plant equipment must be maintained in good working condition at all times.

Good maintenance of equipment provides effective and efficient operation and cuts down on expensive breakdowns and manpower requirements.

A GOOD MAINTENANCE PROGRAMME REQUIRES:

1. *definition of the types of maintenance for accounting purposes*
2. *knowledge of the process and equipment*
3. *data cards for parts and project information*
4. *frequency maintenance routines to ensure consistent inspection procedures*
5. *a recording system for evaluation of the programme and equipment*

## Preventive Maintenance

*Preventive maintenance is regularly scheduled maintenance,checks and tests carried out to prevent unexpected or untimely breakdowns of equipment.* This reduces costly breakdowns, permits prediction of breakdown time to optimise the time between overhauls, and ensures continuous service. Also included under this heading are equipment modifications.

Breakdown Maintenance

*When a piece of equipment fails, breakdown maintenance is needed to restore it to operation.*

Routine Maintenance

*This consists of daily lubrications, temperature checks, and all other short time maintenance routines which cannot readily be classified.* It includes the work performed under the standing daily maintenance routines.

By applying and dividing a programme into three *categories* the maintenance carried out can be accounted for and evaluated over a period of time to determine its effectiveness.

Process & Equipment

*Complete diagrams* of the plant process, electrical distribution, control panels, and the instrumentation diagrams must be available. These diagrams should show the *continuity* of the process, electrical system and controls, and their *interdependency.* It is necessary to know what *purpose* each part (or piece of equipment) performs, *how it works,* and *how it is expected to perform under ideal conditions.* In addition, the operations personnel must know *what happens to the process if any part fails,* and on failure, *what alternatives exist to keep the system operational.*

THE PREVENTIVE MAINTENANCE SYSTEM

Data Cards (Figure 12-1)

*Data cards* are the *inventory of major equipment.* They are often tedious to fill out but the information

must be correct and complete. Data cards should include information on pump impellers, for example. Data cards enable such *parts* as bearings to be purchased before disassembling a piece of equipment.

Use data cards that can easily be filed in a file-box similar to that shown in Figure 12-4.

Equipment Numbers

The equipment components in a plant should be numbered for easy identification and to simplify recording of data. Any numbering system, as long as it is consistent, may be used. Perhaps the most simple system is one which uses #1 sewage pump, #3 low lift pump, etc.

Frequency of Maintenance

To determine the frequency of inspections and maintenance, use the *manufacturer's guidelines* and *previous experience* as an initial guide. When the system has been used for one or two years, an *analysis of the maintenance system results* will indicate whether the inspection frequency is sufficient, or whether it should be changed. The maintenance programme must be *tailored to meet the needs of any plant.*

Maintenance periods are usually divided into *monthly, 3-monthly, semi-annual and annual categories. Daily and weekly* (which are associated with the daily) checks, etc., are also required. This daily type of maintenance may only take a total of an hour or so each day on a number of pieces of equipment. *A daily work standing order card* is sufficient, incorporating any

## EQUIPMENT DATA

EQPT. No

EQPT No

EQPT. No

EQPT. No.

ROJECT

QUIPMENT TITLE

AKE

ODEL SERIAL No RPM HORIZ./VERT

RANSMISSION SIZE/CAP.

IMPELLER DIA.

EARINGS SHAFT DIA.

EALS

OTOR MAKE

P. AMPS VOLTS SERIAL No.

PM TYPE CODE FRAME

ITY TEMP DESIGN S.F.

ARINGS

OTOR CONTROLS

EATERS

Figure 5-1 DATA CARD (FRONT)

## EQUIPMENT DATA

Figure 5-1 DATA CARD (BACK USED FOR ADDITIONAL INFORMATION AND SPARE PARTS INFORMATION.)

FINAL TANK #3    GEAR UNIT   08-19-05-1C-03        PROJECT:

Worm Gear - Recommended Oil

0 - 40°F.   AGMA 5EP   Shell Macomo   72 or equal

30 - 125°F.   AGMA 8EP   Shell Macomo   978 - 82 or equal

1. Check all mounting bolts and nuts are secured.
2. Check alignment.
3. Check for any signs of increased vibration.

Typical Frequency Maintenance (or Depth) Card       (Front)

Figure 12-2

MAINTENANCE PERFORMED AS SPECIFIED

| DATE | BY | DATE | BY | DATE | BY |
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Figure 12-3    Typical Frequency Maintenance Card       (Back)

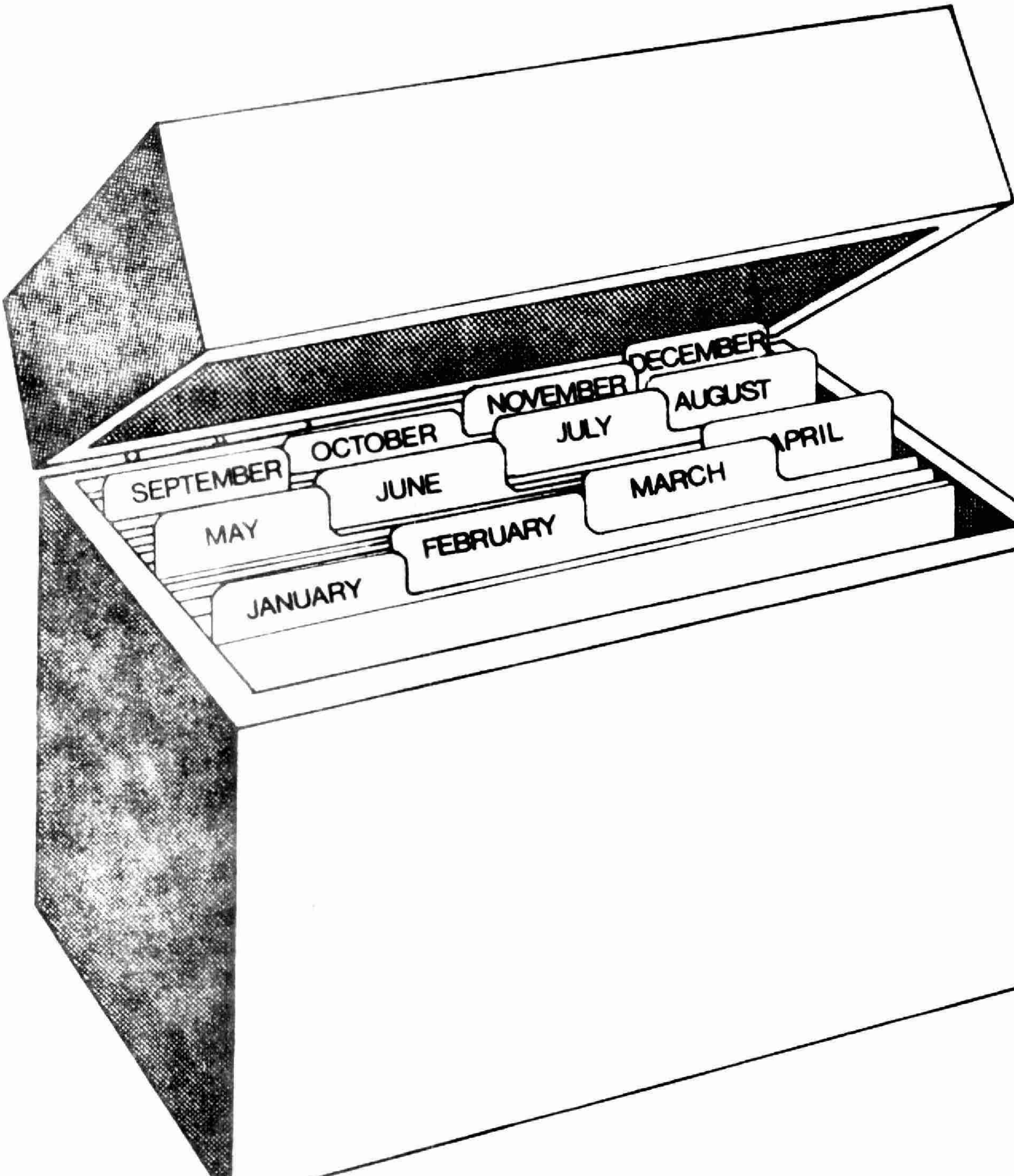


Figure 5-4 **FILE BOX**

weekly maintenance, the total time being allotted to the routine maintenance category.

The monthly, 3-monthly, semi-annual and annual maintenance may require one, two, or more man hours per piece of equipment and must be controlled separately with time allotted for each piece of equipment. *Coloured cards* (Figures 12-2 and 12-3) are used to denote the *frequency of maintenance:*

*blue - monthly*
*green - 3-monthly*
*orange - 6-monthly*
*yellow - annually*

Prepare such cards for equipment, and *stagger them throughout different months of the year.* This makes a fairly even work load available to the work force in any particular month. *A small file box* and *indexed month cards* (January, February, etc.) make this a very simple reminder system (Figure 12-4).

The coloured frequency maintenance cards have the *equipment name, number and project* noted on the front. The front of the cards also shows the *"checks"* to be made and includes the lubrication instructions (if any). The colour denotes the frequency of maintenance.

The *"checks"* will ensure *consistency of inspection.* **Listing** the checks and work to be completed ensures that *all knowledge is not vested in one person*

and, in the case of absence or termination, another person can step in to do the necessary work. The list also helps in *supervising the system.* A person with a check list is more apt to carry out the checks and not just indicate, without actually doing the checks, that the inspection was completed.

Inserting the work to be done on the frequency maintenance (depth) cards is a task which must be done well for a successful preventive maintenance programme. This provides a *consistent preventive maintenance package.* Maintenance noted on a card such as "inspect, repair and comment" is vague and can lead only to inconsistency and poor maintenance. *Maintenance manuals must be read* and *thoroughly understood, experience drawn on,* and the necessary maintenance details briefly outlined on the cards.

*As an example of frequency control, in the month of July one may find three orange cards for motors, three green cards for pumps (3-month check), three orange cards for electrics (6-month check), a blue card for aeration equipment (monthly check) and a yellow card for a boiler (annual check). At the beginning of the month, these cards are taken out of the file box, put in a monthly work holder of some type, and the work scheduled for July. When work is completed the back of the card is initialled and dated, and the card returned*

*to the file box according to its frequency (the green cards would be put under the month of October, the orange cards under the month of January, etc.)*

*A master schedule* (Figure 12-5) should show equipment and when preventive maintenance work is required. It gives an *overall picture* of the system and provides an *easy check that cards are in the correct rotation order* for supervision of that programme.

Posting a preventive maintenance system on a board similar to that of the master schedule, with coloured pins to show the different frequency work loads and which equipment requires inspection in each month, provides the operations/maintenance personnel with an *overview of the preventive maintenance scheme and frequencies.* The *visiting public* can learn from the board how the municipality is trying to protect their environment and at the same time provide continuity of service.

## Predictive Tests

Record load checks such as: *voltage, current, megger tests, vibration readings, bearing shock pulse tests, temperature indications*, etc., to *show any trend.* For example:

a) is the current reading consistent?

b) is the temperature reading increasing?

These are the *predictive tests* of the preventive maintenance system used to determine any deterioration in results.

| EQUIPMENT | EQUIPT No. | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| COMMINUTOR | | ● | ● | ● | ◓ | ● | ● | ● | ● | ● | ◓ | ● | ● |
| COMMINUTOR - MOTOR | | ● | ● | ● | ◓ | ● | ● | ● | ● | ● | ◓ | ● | ● |
| No. 1 RAW SEWAGE PUMP | | | | ◓ | | | ○ | | | ◓ | | | ○ |
| No. 1 MOTOR | | | | ○ | | | ○ | | | ○ | | | ○ |
| No. 1 VALVES | | | | ○ | | | ○ | | | ○ | | | ○ |
| No. 2 RAW SEWAGE PUMP | | | | ◓ | | | ○ | | | ◓ | | | ○ |
| No. 2 MOTOR | | | | ○ | | | ○ | | | ○ | | | ○ |
| No. 2 VALVES | | | | ○ | | | ○ | | | ○ | | | ○ |
| RETURN PUMP - V.S. | | ● | ● | ◓ | ● | ● | ● | ● | ● | ◓ | ● | ● | ● |
| PUMP MOTOR | | | | ○ | | | ○ | | | ○ | | | ○ |
| PUMP VALVES | | | | ○ | | | ○ | | | ○ | | | ○ |
| REEVES DRIVE | | ● | ● | ◓ | ● | ● | ● | ● | ● | ◓ | ● | ● | ● |
| RETURN PUMP - C.S. | | | | ◓ | | | | | | ◓ | | | |
| PUMP MOTOR | | | | ○ | | | ○ | | | ○ | | | ○ |
| PUMP VALVES | | | | ○ | | | ○ | | | ○ | | | ○ |
| SLUDGE PUMP | | ● | ● | ● | ● | ◓ | ● | ● | ● | ● | ● | ◓ | ● |
| PUMP MOTOR | | | ○ | | | ○ | | | ○ | | | ○ | |
| PUMP VALVES | | | ○ | | | ○ | | | ○ | | | ○ | |
| SLUDGE PUMP-REDUCT | | | | | | ◓ | | | | | | ◓ | |
| SUMP PUMP | | | | ◓ | | | | | | ◓ | | | |
| CHLORINATOR | | | | | | ◓ | | | | | | ◐ | |
| CHLORINE LINES | | | | | | ◓ | | | | | | ◐ | |
| FLOW METER | | | | | ◐ | | | | | | | | |
| EXHAUST FAN (CHLOR.) | | | | | | | ◐ | | | | | | |
| CHLORINE SCALE | | | | | | | | | | | | ◐ | |
| BOILER | | | | | | | | | | ◐ | | | |
| MOTOR CONTROLS | | | | | | | ◐ | | | | | | |
| FINAL CLARIFIER | | ● | ● | ● | ◓ | ● | ● | ● | ● | ● | ◓ | ● | ● |
| CLARIFIER MOTOR | | ○ | | | ○ | | | ○ | | | ○ | | |
| CLARIFIER REDUCER | | ○ | | | ◓ | | | ○ | | | ◓ | | |

PREVENTIVE MAINTENANCE BOARD

LEGEND: ● - 1 MONTH ○ - 3 MONTHS ◓ - 6 MONTHS ◐ - ANNUAL

Master Schedule

Figure 5-5

In-Plant Recording (Figure 5-6 )

Records should be kept in a ring binder *log book. Each piece of equipment has a separate page* in this book, with the following information recorded:

*a) work done*

*b) time spent*

*c) costs for any piece of equipment*

*The accuracy, usefulness and reliability of the maintenance system depend upon the conscientious completion of this log book.*

Information which can be obtained from records in a log book:

*a) comparison of existing equipment*

*b) major faults and problems*

*c) evaluation of the maintenance system*

*d) evaluation of maintenance and reliability of equipment as a basis for selection of future equipment.*

*e) evaluation and comparison of maintenance costs for equipment*

*f) measures of performance and effectiveness of equipment and maintenance*

*g) information for discussions with suppliers and the provision of "feedback".*

Any preventive maintenance system is only a part of the overall maintenance function; its application must be reviewed with this in mind. *An evaluation of the*

Equipment Name :
Equipment Number:

| DATE | WORK DONE, MATERIALS & CATEGORY | | MAN HOURS | [illegible] | | MATERIAL | |
|---|---|---|---|---|---|---|---|
| | | | | COST | TOTAL | COST | TOTAL |
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Figure 12-6 Typical Log-Book Page

*success or deficiencies of the preventive maintenance scheme can be obtained only if total maintenance data is recorded.* The *costs* of preventive maintenance and breakdown maintenance must somehow be *minimized.* To achieve this, complete maintenance data must be available.

There is no magical mathematical formula to establish how much maintenance should be done. Whenever treatment is incomplete, the question to be asked is *"Was enough maintenance done to prevent equipment failure?"*

Not only does *poor service annoy the consumer* but all water and sewage operators and maintenance personnel have a *moral responsibility* to ensure that the total environment, water quality, and service is not impaired.

*Good maintenance in water and sewage works is in the hands of the operators and maintenance personnel.*

**SUBJECT:**

BASIC WATER TREATMENT OPERATION

**TOPIC:** 6

CHLORINATION, *including Bulletin 65-W-4*

## OBJECTIVES:

Trainee will be able to:

1. Determine the purpose of chlorination;
2. Identify 4 methods used to determine a chlorine residual;
3. Determine the steps to follow in using the OT test;
4. Determine the purpose of Bulletin 65-W-4;
5. Determine the nature and type of chlorination that is required in a water treatment plant; (see Bulletin 65-W-4)
6. Determine routine operation to follow in chlorination (see Bulletin 65-W-4);
7. Determine the steps to follow for disinfection of new works.

# CHLORINATION

## PRINCIPAL PURPOSE

The principal purpose of chlorination is *DISINFECTION* - killing bacteria and viruses harmful to man. The chlorine does not kill the bacteria and viruses directly but mainly by forming hypochlorous acid (free residual chlorination) when the chlorine gas and the water are mixed together in the chlorinator. At the same time, an equal amount of hydrochloric acid is produced which reacts with the alkalinity in the water. *In case of very heavy chlorine dosages, the acid can seriously reduce the pH and cause corrosion.*

## OTHER PURPOSES OF CHLORINATION include:

Control of taste and odour problems when free or combined residual chlorination is practiced.

Oxidation of iron and manganese, nitrites, and ammonia, or the destruction of phenols and the control of algae and slime growth by free residual chlorination.

If too little chlorine is added, the taste and odour problems may become severe.

When chlorine is added to water for disinfection, it reacts with any organic and inorganic materials that are present. Such reactions complicate the disinfection process because the chlorine demand of these materials must be satisfied as well as those associated with the disinfection reactions.

## CONTACT TIME

*Contact time* is the amount of time required to allow the chlorine to kill bacteria and viruses present in the water supply. *A minimum contact time of 15 minutes is recommended.*

Always add chlorine at a point where complete mixing will occur.

## GENERAL WATER QUALITY CONSIDERATIONS

To chlorinate, consider the amount of pollution in each water supply.

For example, add one milligram per litre (mg/l) chlorine to a chemically clean water like Lake Superior, which contains some bacteria but no ammonia or proteins. The chlorine will kill all the bacteria in seconds.

On the other hand, add one mg/l chlorine to a chemically dirty water like the Grand River, and the hypochlorous acid will react with ammonia and proteins from sewage, industrial wastes, algae and land drainage to form chloramines (compounds of organic or inorganic nitrogen and chlorine). These chloramines can take hours to kill the same number of bacteria that are killed in seconds by free residual chlorination (hypochlorous acid). Furthermore, the chlorine can react with other materials in the water, such as iron and non-protein organic matter, and be completely consumed without disinfecting anything.

So the amount and type of chlorine residual used is controlled by:

(a) Degree of chemical and bacterial pollution;

(b) Period of contact available in the plant from application of chlorine to the first consumer.

## MINISTRY OF THE ENVIRONMENT CHLORINATION OBJECTIVES

The Ministry of the Environment has set up minimum objectives (see *M.O.E. Revised Bulletin 65-W-4)* for chlorination of public water supplies. These objectives are set up on the broadest concept to protect the maximum number of consumers at any one time. *Occasionally these minimum objectives will*

*have to be exceeded in water plant operating practice and a higher residual may have to be used.*

An operator can follow the guidelines in meeting the minimum objectives, but still produce a water contaminated with coliform bacteria. In such cases, public health is in danger. Immediate changes in the chlorination program must be made, such as:

(a) Increase the chlorine residual;

(b) Change the type of residual;

(c) Change the point or points of application;

(d) Increase the contact time between point of application and the first consumer.

The water utility is an industry producing a saleable, potable product. As such, certain quality control measures are required. One of these is the chlorine residual analyser and recorder. This equipment must be kept in proper operating order. The record of chlorine residual provides the operator with positive proof of performance.

*The chlorine residual must be checked and recorded at least once every 8-hour shift.* The residual is maintained at or above the minimum required for the plant. These requirements are set by the Ministry of the Environment Regional Engineer (Sanitary Engineering Branch) who uses *M.O.E. Bulletin 65-W-4* as a guide.

## pH AND ITS EFFECT ON CHLORINATION

The pH of a water is an indication of its acidity (below 7.0) or alkalinity (above 7.0). It can be lowered to corrosive levels by the addition of chlorine, alum and other coagulants. In some cases, the pH of the raw water may already be too low. Regardless of the cause of low pH, it should be corrected to prevent corrosion by adding an appropriate alkali before the water goes to the distribution system. *All chlorine compounds are most effective in bacteria and virus destruction at low pH.* Any pH correction upwards (above 7.5) should be done *after* the chlorine has done its work.

## IMPORTANCE OF TURBIDITY REMOVAL IN WATER TREATMENT

In the chlorination of water, no mention is made of the effects of turbidity because it is assumed that the water meets the turbidity requirements of 1 unit maximum. However, *bacteria can be concealed within the turbidity particles and be immune to the effects of chlorination.* Turbidity removal improves the appearance or clarity of the water and prevents the accumulation of mud in the distribution system. However, turbidity removal is also very important because it eliminates "chance bacteria contamination" as well.

## CHLORINE RESIDUAL DETERMINATION

Four common methods for determining chlorine residual in water are:

(a) Orthotolidine (OT)
(b) Starch iodide
(c) DPD method (Palin)
(d) Amperometric titration

### (a) Orthotolidine (OT) Test

The OT method is an old one dating back to 1914, and is still used in most plants. It is good for determining total chlorine residual but the free chlorine residual results obtained are only accurate if the water being tested is near $0^{\circ}C$. Nitrites, iron, and highly oxidized manganese can cause a false colour. The OT method is being replaced by the DPD and the Amperometric methods in water plants. However, a check control is usually maintained with the OT method, especially in the case of the latter method.

To proceed with the test, allow 15 minutes contact time (or longer) in the chlorine chamber or filters to disinfect the water and meet its demand for chlorine. Take a sample and test for *total* chlorine residual by adding the sample to the OT reagent in a glass tube or glass container. To test for *free* chlorine residual add the OT reagent to the sample which should

be at or near the freezing point. A yellow colour in the sample indicates the presence of a chlorine residual. The deeper the yellow the greater the residual. A lemon yellow colour indicates a safe residual for drinking water.

Free chlorine residual can be distinguished from combined residual under given conditions of time and temperature. The colour caused by free chlorine residuals develops instantly at low water temperatures after the OT reagent is added to the sample. Colour caused by the combined residual develops more slowly and may take up to 20 minutes to reach its maximum. At higher water temperatures the colour develops rapidly for both free and combined residuals.

(b) Starch Iodide Method

The starch iodide method of residual determination is used more often at sewage treatment plants and at water works operations where higher chlorine residuals are encountered.

(c) DPD (Palin) Method

The DPD method is judged the best colorimetric method for free chlorine in water.

Both free and combined chlorine residual can be analyzed by this method. Differentiation between the free and combined forms of chlorine residual simplify the control of modern chlorination processes.

A novel feature of the Lovibond Comparator method lies in the use of compressed tablets, which are more convenient to use, and permit a procedure of exceptional simplicity.

(d) Amperometric Titration Method

The most accurate method of measuring free and combined chlorine residuals is by the Amperometric titration

procedure. This method uses an electric current measuring device to indicate when the chlorine or chlorine indicator has been removed by a titration process.

*Phenylarsine oxide* is the reducing agent normally used as the titrating agent. It reacts with free chlorine residuals at pH 6.5 to 7.5 in a quantitative manner.

By conducting a two-stage titration with the pH adjusted at about 7 and then at about 4, free and combined chlorine residuals can be measured separately. Interference from nitrites and oxidized forms of manganese are eliminated by conducting the titrations at pH levels above 3.5.

O N T A R I O

MINISTRY OF THE ENVIRONMENT

SANITARY ENGINEERING BRANCH

# CHLORINATION OF POTABLE WATER SUPPLIES

Technical Bulletin 65-W-4

Revised September, 1973

# CHLORINATION OF POTABLE WATER SUPPLIES

## I N D E X

# CHLORINATION OF POTABLE WATER SUPPLIES

## 1.0 INTRODUCTION

### 1.1 Purpose of Bulletin

To provide a minimum standard of design and operation of chlorination facilities. New installations should meet the criteria as set out in the bulletin and existing facilities are to be brought up to standard in a reasonable length of time.

### 1.2 When Disinfection Required

Treatment by continuous and adequate disinfection is required when the supply is obtained from a surface source; when the supply is exposed to contamination during treatment; when ground water sources are or may become contaminated, as in fractured limestone areas; or where local conditions, such as flooding, indicate the need.

## 2.0 EQUIPMENT

### 2.1 Capacity

Chlorination equipment shall have a maximum feed capacity at least 50 per cent greater than the highest expected dosage required to provide a free chlorine residual. In addition each gas chlorinator not supported by additional standby units of equal capacity shall have a conversion kit sized to double the capacity of the machine.

### 2.2 Chlorinators and Controls

Dependable feed equipment, either of the gas feed or positive displacement solution feed type, shall be used for adding chlorine. Automatic proportioning of the chlorine dosage to the rate of flow of the water treated shall be provided at large plants and at all plants where the rate of flow varies without manual adjustment, or operation, of valves and/or switches.

### 2.3 Duplicate Equipment

Chlorine feed equipment at plants providing chlorination to ensure the safety of the supply shall be installed in duplicate, to provide uninterrupted operation of equipment during times of breakdown. In addition, spare parts consisting of at least the commonly expendable parts such as glassware, rubber fittings, hose clamps, and gaskets, should be provided for effecting emergency repairs.

For a multi-well supply system requiring chlorination for disinfection, the standby requirement may be met by one portable unit.

### 2.4 Weigh Scale

When gas feed chlorinators are employed, a set of corrosion resistant scales should be made available for weighing the chlorine cylinders serving each operating chlorinator.

### 2.5 Hypochlorite Solution

Where a powdered product is used, hypochlorite solutions shall be prepared in a separate tank. The solution is allowed to clarify before it is directed to the solution storage tank serving the hypochlorinator.

### 2.6 Safety Equipment (Gas application only)

Each plant shall have readily available, a self-contained or air-supplied type of respiratory protective equipment. Smaller installations may make arrangements with a local fire department or other agency for the loan of the required equipment on an emergency basis with a canister type mask being located at the plant.

When a canister type mask is used in place of a self-contained or air-supplied unit the operators must be made fully aware of its limitations and the location of the more adequate equipment.

One respirator shall be immediately available, located in a conspicuous location outside the area of probable contamination.

Protective clothing including gloves, goggles and safety shoes shall be available for persons handling chlorine.

Eye wash fountains shall be available in case of accident.

Preferably weigh scales for 150 pound cylinders shall be recessed in the floor

Safety chains shall be used to retain 150 pound cylinders, either in storage or on weigh scales, in a safe upright position.

### 2.7 Building Detail (Gas application only)

Gas chlorine equipment - chlorinators, weigh scales, chlorine cylinders - must be located in an isolated building, room or rooms. In larger installations the storage and scale facilities should be in a room separated from the chlorinators. The construction of the room or rooms should be of fire resistant material and have concrete floors.

Ton cylinders shall be stored on their sides on level racks, between four and eight inches off the grade. Chlorine should not be stored below ground level and the cylinders must be protected from excessive heat, dampness, and mechanical damage.

Areas containing chlorine or chlorinator equipment shall be clearly marked "DANGER! CHLORINE STORAGE" or "DANGER! CHLORINE FEED EQUIPMENT" as applicable.

The exit doors shall be hinged to open outwardly. There shall be two or more exits if the distance of travel to the nearest exit exceeds 15 feet. In each case, one door should be on an outside wall.

Continuous mechanical ventilation at the rate of three air changes per hour shall be provided, or screened openings to the outdoors shall be provided within six inches of the floor in the ratio of one square foot per 500 square feet of floor area. Similar openings shall be provided in or near the ceiling. The openings shall be distributed to produce the maximum air circulation across the floor. Secondly, provision for emergency mechanical ventilation should be made sufficient to produce 30 air changes an hour taking suction at a maximum of three feet above floor level.

Th temperature in the storage and scale room shall not be higher, and preferably slightly lower, than that in the chlorinator room. The gas lines between the scales, chlorinators and injectors shall not be located on an outside wall or in a location where low temperatures may be encountered.

### 2.8 Testing Equipment

All installations must be equipped with a permanent standard chlorine residual comparator test kit. When free residual chlorination is mandatory an amperometric titrator is also required.

In larger installations, or where poor raw water quality and/or minimum supervision indicates a hazard, an automatic residual analyzer and recorder is required. The chlorine residual recorder shall be equipped with a low residual alarm and installed to measure the chlorine residual in the water leaving the plant.

## 3.0 ROUTINE OPERATION

### 3.1 Chlorine Residual

For complete water treatment plants which effect both pre- and post-chlorination, or when a minimum of two hours contact time is assured before distribution after the application of chlorine, or for ground or protected surface water supplies, proven to be materially free from bacterial and viral contamination, the minimum chlorine residual shall be 0.2 mg/l. For all other water supplies the minimum chlorine residual shall be 0.5 mg/l.

The chlorine residual test is performed on a sample of the plant or pipe line-effluent, after it has been held for 15 minutes.

When ground water sources are proven to be free from possible viral and/or bacterial contamination they may be exempted from chlorination.

As circumstances demand the minimum requirements for chlorine residual may be increased.

A free residual chlorination program may be made mandatory, depending on the source of supply and treatment works, and it is a preferred method of treatment.

It is suggested that a chlorine residual be maintained in all active parts of the distribution system.

The selection of appropriate disinfection procedures are contingent upon the results of bacteriological and other evaluations on the total water system including the source of supply.

### 3.2 Chlorine Application Points

Where possible pre- and post-chlorination shall be practised. When only post-chlorination is possible free residual chlorination should be considered, and a minimum contact time of 15 minutes, before the first possible consumer, shall be provided at all times.

### 3.3 Chlorine Residual Test

The following procedure shall be followed in performing the orthotolidine chlorine residual test.

1. Draw sample of chlorinated water. The tap should be kept running continuously or for a few minutes before taking the sample.

2. Allow sample to stand for 15 minutes to simulate the required minimum contact period.

3. Use 0.5 ml of orthotolidine (O.T.) reagent in 10 ml cells, 0.75 in 15 ml cells, and five ml in 100 ml tubes. Place reagent in testing tube; add sample to required volume; and mix. When the temperature of the sample is less than 68°F bring it to that temperature quickly after mixing with the O.T.

4. A colour comparison is made when the maximum colour develops.

5. The test results are recorded in the plant records and any necessary alteration is made to the chlorine application rate.

The above procedure is satisfactory for determining the total available chlorine residual. When the free residual is required the sample must be near 32°F when the O.T. is added and the colour comparison is made immediately. The orthotolidine-arsenite (O.T.A.) test can also be used to determine the free available chlorine residual.

The accuracy of an automatic chlorine residual analyser shall be checked daily. This is accomplished using either the amperometric titration or orthotolidine colourimetric test procedures. The results of the check are inscribed on the recording chart along with the date and operator's initials, opposite a mark showing the time of the check.

The chlorine residual test must be performed frequently enough to ensure that an adequate chlorine residual is maintained at all times. Such points as raw water quality and a resultant variation in chlorine demand, and changing flow rates must be taken into consideration. When a residual analyser alarm system is used the testing frequency may be reduced.

### 3.4 Records

Minimum records shall include:

1. daily records of the chlorine used and scale readings,
2. results from all chlorine residual tests,
3. the flow rate and chlorine feed rate at the time of testing,
4. water used and chlorine dosage in mg/l on a daily basis,
5. detail on chlorine cylinder changes, orders and chlorine on hand, and
6. monthly and yearly summaries of chlorine consumption and feed rates.

## 4.0 EMERGENCY OPERATION

Where chlorination is required for disinfection purposes a continuous feed of chlorine must be assured. For this type of service the operating authority shall develop a standby operating procedure to cover emergencies. The procedures developed shall be posted in a prominent location in the plant and all operators shall be made aware of the information thus given.

The emergency information shall include:

1. the order not to pump unchlorinated or inadequately chlorinated water to the distribution system,

2. the name, address and telephone number of -
   (a) senior supervisory personnel,
   (b) medical officer of health,
   (c) Ontario Ministry of the Environment,
   (d) chlorinator service company, and
   (e) chlorine supplier,

3. the order to notify the Ministry of the Environment, and the medical officer of health immediately if unchlorinated or inadequately chlorinated water is directed to the distribution system,

4. details on emergency chlorination procedures,

5. a statement on operator responsibility, and

6. details on announcing a "Boil Water Order" (developed with MOH).

When emergency chlorination is provided the chlorine residual in the water leaving the plant shall be 1.5 mg/l.

When unchlorinated or inadequately chlorinated water has been directed to the distribution system, and until direction is obtained from the Ontario Ministry of the Environment, the chlorine feed rate shall be increased and a program of hydrant flushing initiated to provide a chlorine residual of 1.0+ mg/l in the whole of the distribution system. When increasing the chlorine residual or carrying out an extensive hydrant flushing program, notify all customers who may be adversely affected.

## 5.0 ADVERSE BACTERIOLOGICAL RESULTS

When the results from bacteriological samples collected from the distribution system do not meet the requirements of the Ontario Ministry of the Environment Drinking Water Objectives, the Ontario Ministry of the Environment and the local medical officer of health shall be notified. The Ministry will recommend corrective action suited to the individual circumstances. The recommendation may include one or a number of the following procedures:

(a) the disinfection, for a 24-hour period, of the distribution system with a solution having a starting strength of 50 mg/l of available chlorine;

(b) the initiation of chlorination procedures on an unchlorinated supply;

(c) an increased chlorine residual requirement together with a distribution system flushing and/or swabbing program;

(d) the collection of further samples;

(e) a recommendation to the medical officer of health that a "Boil Water Order" be issued.

## 6.0 DISINFECTION OF NEW WORKS

### 6.1 Preparation

Before disinfection is attempted, all surfaces must be thoroughly cleaned. Pipe lines are flushed with potable water until a "turbidity-free" water is obtained at all ends. Where possible foam swabs should be used to assist cleaning. Reservoirs are to be brushed as required, to obtain clean surfaces, and disinfected as per AWWA Standard D 102-64 or equivalent.

As chlorine is a surface active disinfectant it may not penetrate crevices or particles of debris. Therefore, a thorough cleaning is necessary if the disinfection program is to be effective.

### 6.2 Disinfection

Disinfection may be accomplished by one of the following procedures.

1. In mains all surfaces shall be in contact, for a period of 24 hours, with a chlorine solution having a starting strength of 50 mg/l. If a residual of less than 25 mg/l remains at the end of the contact period the procedure shall be repeated.

2. In large mains a "slug method" may be used, whereby a slug of water containing at least 300 mg/l of available chlorine is moved through the pipe at a rate such that the chlorine is in contact with the pipe for at least 3 hours.

3. To conserve water and chemical, reservoirs may be disinfected by spraying all surfaces with a chlorine solution havin a starting strength of 250 mg/l available chlorine. Special protective clothing and self-contained or air-supplied type respirator must be used by personnel performing the spray procedure and necessary safety precautions adheared to.

4. When surface conditions are not ideal, such as will be encountered in used works, special disinfection procedures will be required. This could include the maintenance of a chlorine residual for an extended period of time.

### 6.3 Testing

After disinfection, and when the chlorine residual in the treated works is at or below the normal operating level, bacteriological samples shall be collected. When a 0.2 mg/l or greater available chlorine residual is to be maintained in or after the new works, one set of satisfactory bacteriological results shall be obtained before the system is placed into operation. Otherwise, a minimum of two sets of coliform-free results shall be obtained before the works are placed in service.

SUBJECT:

BASIC WATER
TREATMENT OPERATION

TOPIC: 7

WATER BACTERIOLOGY

OBJECTIVES:

Trainee will be able to:

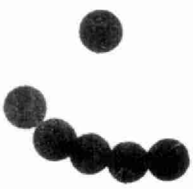
1. Determine the nature and size of bacteria;
2. Determine the sources of bacteria in the water;
3. Give the reason for the use of "indicator" bacteria;
4. Determine the correct sampling procedure for water supplies;
5. Interpret the results of bacteriological lab tests.

NATURE OF BACTERIA

Size and Shape

Scale: $\frac{1}{4}" = 1\mu = \frac{1}{1000}$ mm

COCCUS FORMS



Single

Chain
e.g. Streptococcus

Clump
e.g. Staphylococcus

uniform size 1µ diameter

BACILLUS FORMS

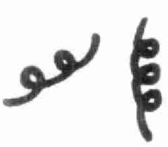
Single

Chain
e.g. Streptobacillus

Clump
e.g. Typhoid Bacillus

.3 - 1.5µ wide 1.5 - 8µ long

SPIRAL FORMS



e.g. Leptospira

.2 - .75µ wide 5 - 25µ long

FOR COMPARISON

ALGAE

e.g. Chlorella

4 - 5µ diameter

# WATER BACTERIOLOGY

## NATURE OF BACTERIA

Bacteria are minute organisms, generally one-celled. They can be seen only with the aid of a microscope, usually only after some kind of staining procedure. There are three basic shapes:

(1) Coccus forms are spherical;

(2) Bacillus forms are rod-shaped;

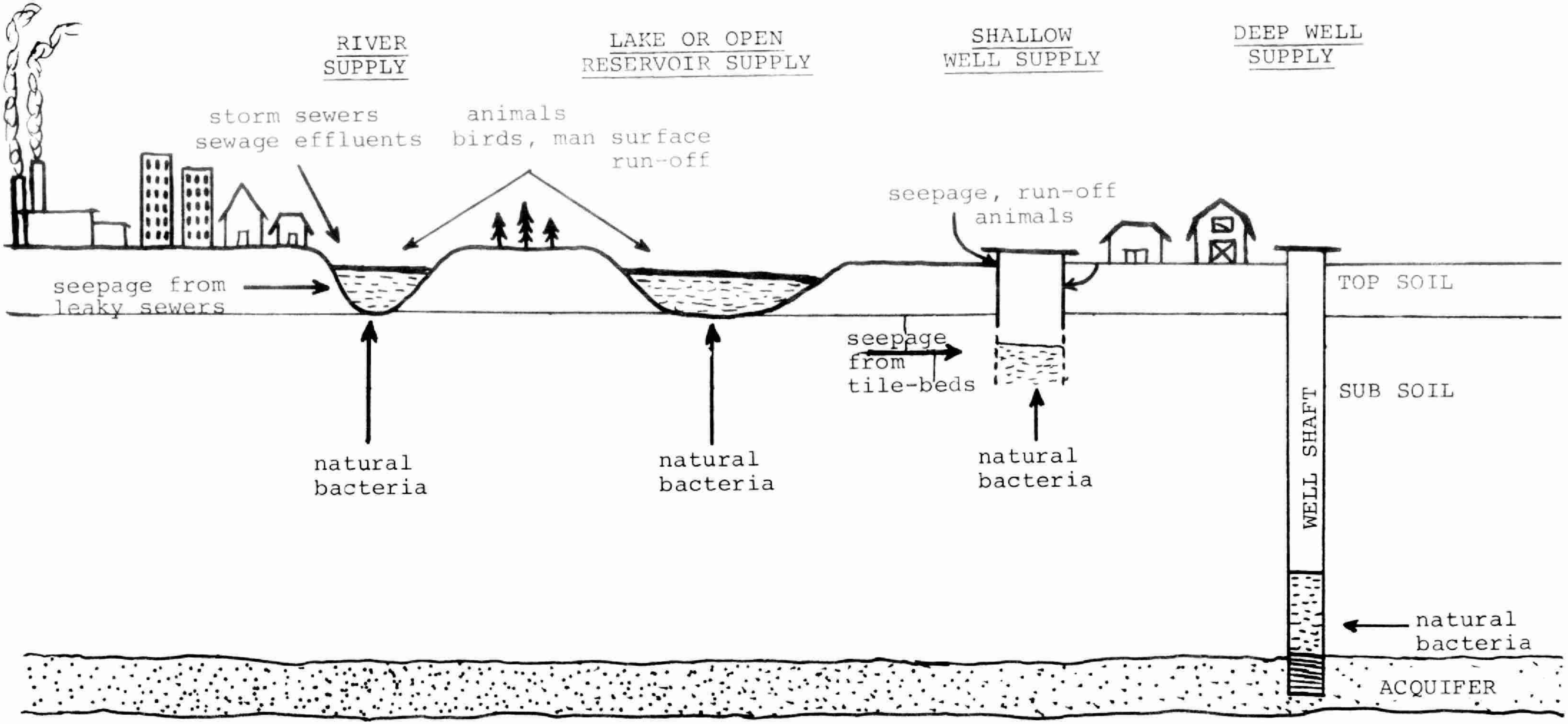
(3) Spiral forms.

Bacteria differ from algae because they do not contain chlorophyll, i.e., they are not green, and they are smaller in size; algal cells can be examined using low power magnification (100 - 200X), but bacteria need a much higher magnification.

The bacterial cells may be attached to one another to form chains, filaments or clumps, and some are capable of movement. The various classes of bacteria can be recognized by the shape of the cells and their metabolic and pathogenic (disease-producing) properties. They can multiply (usually very rapidly), by one cell splitting into two. The speed of multiplication depends on the environmental conditions; an increase in temperature usually results in an increase in the speed of multiplication.

FIGURE 7-1

SOURCES OF CONTAMINATION OF WATER SUPPLIES



Bacteria can be found in almost any location, from hot springs to water-pipe gaskets, and from skin surfaces to the intestinal contents of man and animals.

## BACTERIA IN WATER

There are many sources of bacteria present in any body of water (see Figure 7-1). Many classes of bacteria occur naturally in water, while others may enter the water by being washed off vegetation, soil, farmlands, etc., or by sewage plant and sewer effluents.

In water treatment, the bacteria which are the most important grow and are excreted in the intestinal tract of man and animals. Some are present as normal inhabitants, whereas others are present as agents of disease. One group, made up of several different non-pathogenic (normal) types is the *coliform* group, which is always present in both human and animal solid waste. Persons or animals infected with the so-called enteric diseases, such as typhoid, dysentery, cholera, etc., carry and excrete millions of the disease-producing bacteria along with the coliform bacteria. These bacteria may gain access to a source of water which is supplied for drinking. If this water is consumed, an epidemic of enteric disease can result.

WATER TREATMENT

Since it is difficult to prevent the entry of pathogenic bacteria into a drinking water source, the water must be treated to destroy the pathogenic bacteria before it is delivered to the consumer. At first, treatment of water supplies was begun to prevent the spread of waterborne diseases. Chlorination was introduced in 1910, and was soon followed by additional treatment to produce water free from suspended solids, colour, and unpleasant tastes and odours. Coagulation, flocculation, sedimentation by storage, and filtration, which remove particulate matter from raw water, also remove bacteria. Certain bacteria, however, will remain in suspension so chlorination (or in some places, ozonization) is required to produce a water safe for drinking. *It is important to understand that bacteria can be protected from chlorine by particulate and organic matter, and badly treated or impure waters with high turbidities cannot be completely disinfected by chlorination.* When used as a final process, chlorination should be regarded only as an *additional* safeguard. It should be applied to waters which are clear and of good organic quality.

To destroy bacteria effectively, three things are important:

(1) The amount of chlorine added.

(2) The contact time allowed between the chlorine and bacteria.

(3) The amount of protective particulate matter present in the water.

Because the efficiency of the chlorine process varies due to a breakthrough of particulate matter, increasing organic content of water, or an unusually high level of bacteria in the raw water, the finished water must be monitored bacteriologically. Such monitoring is designed to ensure that sufficient chlorine has been added to kill all pathogens.

Coliforms are bacteria found in the intestine, and are more resistant to chlorine than the bacteria that cause enteric disease. If all the coliforms are eliminated, then all the disease bacteria have been destroyed; where coliforms can still be found, some disease-producing bacteria may also have survived. So the presence of the coliform group of organisms is used as an indicator that proper treatment has not been applied to the water; the water must be considered unfit to drink until the treatment has been improved. Other indicator bacteria are also being used on a large scale, as tests for them are perfected.

## SAMPLING PROCEDURE

The water sample must represent only the condition of the water *at the time of collection*, so the following precautions are necessary:

1. The bottles must be sterile (bacteria free), obtained from the Ministry's Shipping and Receiving Department.

2. The sampler's hands should be washed thoroughly and dried before handling the bottle, to be sure that no bacteria are introduced from that source. When the bottle cap is removed, the inside edges of the cap and the mouth of the bottle must not be handled, and the cap should not be put down.

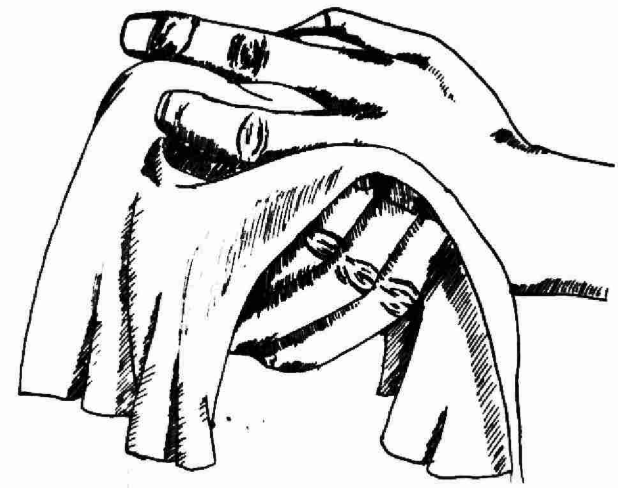
3. From a tap, the water should be allowed to run freely for at least *two minutes before the bottle cap is removed.* When samples are taken from a well, river, stream, lake or open tank, the bottle should be submerged below the surface. Sampling devices, such as a copper wire around the neck of the bottle, should be flame-sterilized before being used. In all cases, the bottle should be filled so as to leave enough air space for proper mixing before analysis.

4. For sampling water that contains chlorine, a bottle containing sodium thiosulphate should be used. The thiosulphate neutralizes any remaining chlorine and prevents it from continuing to kill off any remaining bacteria during shipment of the sample.

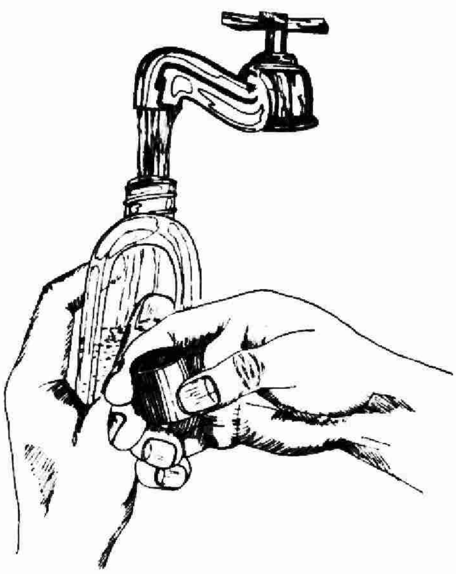
5. The sample report should be filled out in full, giving all the particulars of the sample, and information which may assist the analyser in the selection of the best possible combination of tests for the purpose.

# SAMPLING PROCEDURE

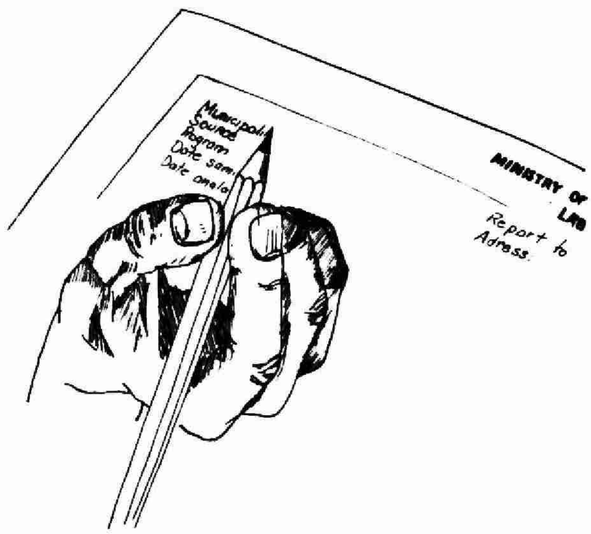
1. Wash hands thoroughly.



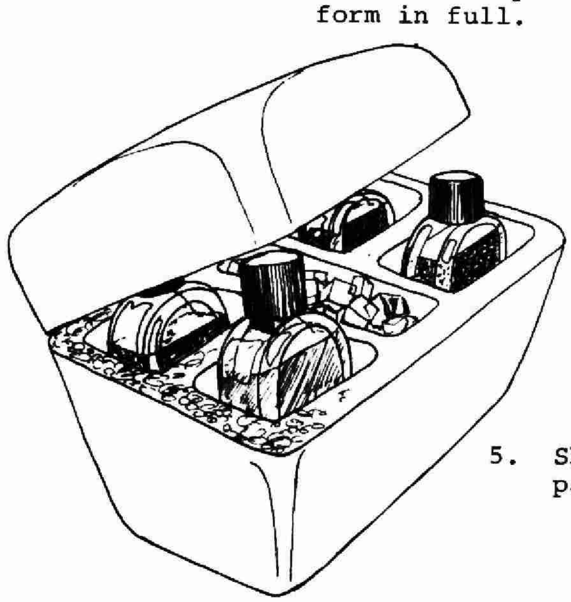
2. Dry hands well.



3. Allow tap to run a few minutes. Hold cap as shown.




4. Fill out sample report form in full.



5. Ship samples packed in ice.

6. The water samples should be shipped to the Ministry laboratory immediately, and should arrive within 24 hours. Refrigeration is desirable, since an increase in temperature in the sample may encourage multiplication of the bacteria and result in an erroneously high count. Special containers are now available for maintaining low temperatures during shipment.

## TESTING PROCEDURE

The main reason for treating public water supplies is to ensure that they contain no organisms which are pathogenic to man. The efficiency of the treatment is determined by testing the water for the presence of indicator bacteria.

An indirect test is used, because analysis for the coliform "indicator bacteria" is faster, easier and safer to perform than direct analysis for the disease producers.

Coliforms and other indicators may be tested for by any or all of three methods:

1. The *Presence-Absence Test* (P-A) shows only the presence or absence of a bacterial group in 50 or 100 ml of sample, but not the actual number of organisms. It is used for coliforms and also flurescent Pseudomonads and clostridia.

2. The *Membrane Filtration Test* (MF), which is often run in conjunction with the P-A test, so that the number of coliform organisms in a sample can be counted. This is normally used in the routine analyses of raw and treated water, and can be used to count fecal streptococci and fecal coliforms.

3. The *Most Probable Number Test* (MPN). This test allows a statistical calculation of the number of coliform organisms present in a water sample. It is useful where the MF procedure cannot be used, such as for turbid water and sewage, which would block millipore filters.

## INTERPRETATION OF RESULTS

The interpretation of the routine bacteriological reports is perhaps the most important aspect. Results are usually expressed as the number of bacteria present per 100 ml of sample. P-A tests are reported using the words "present" or "absent".

Water delivered to the consumer ("finished" water) is expected to conform to certain limits and objectives. To understand these, the properties and characteristics of each indicator organism must be considered separately. Where some bacteria reach undesirable levels, the pattern of the results can sometimes be used to decide the corrective action to be taken.

*Coliforms* are found in the intestine, but can also occur on soils and vegetation. *Fecal coliforms* form a sub-group within total coliforms but, as indicated by their name, are found *only* in human and animal fecal waste; since they die out more rapidly than coliforms, their presence should be considered as a sure indication of recent fecal pollution, calling for immediate action. The repeated presence of coliforms, in the absence of fecal coliforms, may indicate the growth of these bacteria on organic materials in the pipe or on debris, and investigation should be made into possible sources.

*Fecal streptococci* (enterococci) are normally found only in situations where fecal pollution has occurred. They are used as indicators of pollution in the same way as fecal coliforms, and their isolation is especially useful where coliforms are present, but fecal coliforms cannot be found. They are more resistant to chlorination than coliforms and tend to survive longer. Absence of these bacteria shows that disinfection has been adequate.

*Pseudomonas aeruginosa* is a potential pathogen which occurs in sewage. Since it shows some resistance to chlorination, there is growing pressure to include a test for it and other fluorescent pseudomonads in routine examination of potable water. As with the fecal streptococci, the appearance of pseudomonads may indicate that the chlorine dosage is too low and a correction is necessary.

*Clostridia* are a group of organisms which are again mainly used as indicators of fecal pollution, since they are present in sewage and manure. However, these organisms produce very resistant bodies called spores; on account of these, the bacteria can survive in water long after all other indicator organisms have disappeared. These indicators are useful in water supplies that are not sampled frequently. In these cases, chance sampling may give good coliform results, but the water could be dangerously contaminated at intervals in between. Clostridia would probably be isolated in these circumstances and would indicate a need for closer surveillance. The spores are not destroyed by normal chlorination practices, and repeated positive clostridial tests show that treatment was inadequate before final chlorination (e.g., in filtration).

In finished water, there should be NO fecal coliforms, fecal streptococci (enterococci) or pseudomonas aeruginosa. Total coliforms should not be more than 5 per 100 ml of water and the water should be relatively free of fluorescent pseudomonads and clostridia. Where some total coliforms are isolated (at the 5 per 100 ml level or less) they should not be present in more than 10% of monthly samples. Clostridia should not be present in more than 10% of monthly samples.

Treating water supplies properly and efficiently not only ensures freedom from pathogenic organisms, but also yields beneficial side effects. A finished water entering the distribution system with a turbidity of 1 unit or less and

chlorine residual of 0.3 ppm will meet bacteriological standards, and organic material and debris will not enter the lines. *Every effort should be made to achieve these levels.* Where debris enters the lines, bacterial growth and slime formation can occur, with taste and odour and red water problems developing. Correct pH control and/or treatment for the presence of iron will prevent the deposit of rust and iron materials in the line.

A conscientiously applied treatment will prevent the transmission of waterborne disease, deliver to the consumer a clear, palatable product, and maintain a trouble-free system.

<u>BACTERIA INDICATORS OF SEWAGE CONTAMINATION IN WATER TREATMENT</u>

| | COLIFORMS | | | | | |
|---|---|---|---|---|---|---|
| | Total | Fecal | | Pseudomonas Aeruginosa | Fluorescent Pseudomonads | Clostridia |
| | | Fecal Coliforms | Fecal Streptococci | | | |
| Usual Test | MF | MF | MF or P/A | P/A | P/A | P/A |
| Reported | Numbers/ML | Numbers/ML | Numbers/ML | + or - | + or - | + or - |
| Maximum allowable limit | 5/100 ml in monthly samples | Absent | Absent | Absent | Few | 10% samples positive |
| Source | Sewage, Soil Vegetation | Fresh Sewage | Sewage | Sewage | Soil, Water Sewage | Old Sewage Manure |
| Indication | a) Possible contamination with sewage | Definite contamination with fresh sewage | Definite contamination with sewage | Improper Treatment | Improper Treatment | Improper Treatment prior to chlorination |
| | b) Improper Treatment | | Improper Treatment | | | |
| | c) Growth in System | | | | | |

REFERENCES

The following references are provided for those who may wish to add to their library. These texts are not specifically confined to the bacteriological section but contain information applicable to any section of the course.

1. Water Quality and Treatment. A Handbook of Public Water Supplies. 3rd Edition. Prepared by the American Water Works Association, Inc., McGraw-Hill, Book Company.

2. Water Treatment and Examination. Edited by W.S. Holden, 1970. Published by Williams & Wilkins.

SUBJECT:

BASIC WATER TREATMENT OPERATION

TOPIC: 8

SAFETY

OBJECTIVES:

Trainee will be able to:

1. List 2 hazardous jobs that require protective equipment

    (a) for the eyes and face and name the equipment;

    (b) for the feet and name the equipment;

    (c) for the head and name the equipment;

    (d) for the hands and name the equipment;

    (e) for the lungs and name the equipment;

2. List at least 7 rules of safety in and around the plant;

3. List 4 safety signs that should be on display in pumping stations;

4. Describe action to take in case of fire; know the 2 types of fire extinguishers and be able to identify the type of fire each is effective on;

5. State 5 precautions to take when doing electrical maintenance;

6. State 4 precautions to take when handling chemicals.

# SAFETY

## INTRODUCTION

The greatest asset a treatment facility has is its personnel. Since it is good business to protect any assets, municipal authorities must institute well coordinated and vigorous safety programs at all treatment works.

## PROTECTIVE SAFETY EQUIPMENT

The need for protective safety equipment in an accident prevention program has proven its value many times; the program cannot be successful if any phase of accident prevention is overlooked.

*Use safety equipment as it was meant to be used.* This should be compulsory during the performance of hazardous jobs.

*Protect eyes and face* when there is any possibility of injuries from hand tools, power tools, welding equipment, etc.

*Protect feet* with safety shoes to safeguard against injuries while breaking pavements, tamping trenches, handling materials, etc.

*Protect head* (with hard hats) to prevent serious injuries in construction, excavation or electrical work.

*Protect hands* (with gloves) to prevent injuries from occurring when handling materials, sharp objects, chemicals or electrical equipment.

*Use air packs* when hazards such as chlorine, painting or dusty areas exist.

*Prevent accidents due to falls* by using safety belts, scaffolds, etc.

# SAFETY - IN AND AROUND THE PLANT

When working at the plant, observe the following common sense rules:

Keep walkways clear of loose objects such as pails, shovels, loose rope, etc.

Wipe up grease and oil *immediately*; salt or sand icy walks.

Pick up all tools, clean them and return them to their storage area.

When it is necessary to use tools in an empty tank or manhole, etc., lower them in a pail on a rope and remove them in the same way. Brooms and shovels can also be transported by rope. *Do not attempt to climb up and down ladders with your hands full of tools.*

*Do not* overload yourself when using stairways. Keep your load small enough to be able to see over it. Always keep one hand free to use the hand-rail.

*Do not* try to climb up or down a ladder or over a railing when handling a hose under pressure.

Always wear hip wader rubber boots with good treaded soles when washing down the floor of any tank. *Do not* wear rubber boots with worn soles and heels.

Always wear the rubber clothing provided when working in a narrow or confined passage where grit or sludge accumulates.

Always wear rubber or plastic coated, waterproof gloves when cleaning pumps, handling hoses, removing grit or sludge, etc.

When it is necessary to use an extension ladder to enter any empty tank, use the collector arms in the clarifiers to backstop the ladder legs. In an aeration tank, lash the ladder. Enter the tank from a walkway (not from a narrow dividing wall) and *always lash the ladder to a hand-rail.*

Always wear hard hats when working below ground level (in tanks, manholes, etc.) or under scaffolding.

*Do not* hang clothes on electrical disconnect handles, light switches or control panel knobs.

Replace all manhole covers and trap doors to wells. Close after using. If it is necessary to leave them open, *protect them with guard-rails.*

Use the proper tool when removing or replacing manhole covers. *Do not* attempt to move or close a manhole cover with your hands.

When working in manholes located in a street or road, post signs with blinking amber lights and red flags at each approach to the area.

*Do not* pull up grit-filled pails by rope when removing from tanks or wet wells. Use an "A" frame and pulley or some other type of support with a pulley. Be sure the support and pulley are fastened firmly to prevent them from toppling over during use.

*Always wear a safety belt* with a short rope and a safety snap when leaning out through the railings over any tank (or cleaning out spray nozzles, etc.).

# SAFETY - PUMPING STATIONS

## YOU NEED:

*Fire Extinguisher*

*Signs:* "START VENT BEFORE ENTERING"
"DANGER: PUMPS ON AUTOMATIC TIMER"
"NO SMOKING"
"DANGER - DO NOT START"

*Switch lockouts for comminutor controls, etc.*

DRY WELL

Start vent fan before entering the pumping station and *leave it operating continuously* while the operator is in the station.

Post *"DANGER: PUMPS ON AUTOMATIC TIMER"* signs at the control panel floor level, and the pump floor level.

Post *"NO SMOKING"* signs at the pump floor level.

Use *lockout* switches at control panel when working on any pump at floor level.

Safe practices are necessary with gasoline and oil storage, gear shifts, exhausts and repairs. *Do not* store gasoline within a building except in an approved safety can. *Be very careful* during repair work on fuel systems of gasoline engines. *Close the shutoff valve* from the tank and *be sure there is adequate ventilation* while draining the fuel system.

*Check* the ventilation of any enclosed or underground areas when gasoline operated pumps are to be used.

*Do not* refill a gas engine when in operation or while still hot. *Remove* spark plug from engine before cleaning out pump unit.

## WET WELL

*Start* vent fan before entering and keep it in constant operation while operator is in the area.

Use only waterproof and explosion proof extension cord lights.

*Do not* enter a wet well if there are strong odours present. If it is not possible to exhaust the gases with the vent fan, *check* the well with an explosion meter. If a reading of .2 (or 20%) or more is recorded, then self-contained air packs must be worn.

Wear a safety harness and rope when cleaning the wet well or servicing pump controls. *(This is a Ministry of Labour requirement.)*

Entry into any well, sewer, or underground room having no mechanical ventilation system will be done in accordance with the Industrial Safety Act, 1972, and shall be recorded in the daily log.

When maintenance work or cleanout is required in the wet well of a pumping station of a one-man plant, the operator must enlist the aid of another man, to stand by above for emergencies, while he is in the wet well.

## FIRE EXTINGUISHERS

*Set up a plan of action* in case of fire. Mark location of fire extinguishers by painting wall at that point a bright red square with diagonal yellow stripes.

Each operator should have first hand knowledge of fire extinguisher, its ABC rating point of contact and time of operation.

The approximate operating time for $CO_2$ extinguishers is listed here for your information. Dry powder extinguisher operational time is approximately the same as $CO_2$.

| | | | |
|---|---|---|---|
| 2 1/2 | lbs.: | 10 sec. $\pm 2$ sec. | 2* BC.** |
| 5 | lbs.: | 14 sec. $\pm 2$ sec. | 4 BC. |
| 10 | lbs.: | 14 sec. $\pm 3$ sec. | 6 BC. |
| 15 | lbs.: | 25 sec. $\pm 4$ sec. | 8 BC. |
| 20 | lbs.: | 30 sec. $\pm 4$ sec. | 8 BC. |

The 2 BC., etc., refers to the type of fires and area the extinguisher covers.

** BC indicates electrical, gas, oil type fires. "A" types are wood, paper, etc.; $CO_2$ will not be effective on "A" type fires.

* 2 indicates the extinguisher will put out a fire of not more than 2 square feet in area.

Weight indicated refers to contents only.

# SAFETY - LABORATORY

## YOU NEED:

*Protective clothing*

*Marked container for broken glass*

*First aid kit*

## SAFETY HINTS

*Do not* use laboratory glassware for food.

*Practice good housekeeping.* Keep all unnecessary equipment out of working areas.

*Keep areas* around sinks and taps clear. You never know when you will have to wash chemicals off your hands quickly.

Wipe up all spills *immediately.*

Label all reagent bottles *clearly* so they can be identified. The date when the reagent was made up, or received, should be on the label since some chemicals, especially nitrogen compounds, become unstable with age.

When diluting, always add concentrated acids or bases *slowly* to the water, allowing time to cool. Use only heat resistant (Pyrex) glassware. When diluting sulphuric acid, or when making up a solution of sodium hydroxide, *cool the solution in a water bath.*

*CAUTION: Chromic acid cleaning solution is a mixture of sodium or potassium dichromate in concentrated sulphuric acid. It dehydrates and oxidizes most organic matter, including clothing.* Treat it with care!

*Use water as a lubricant* when making glass-to-hose connections. For vinyl tubing, hot water can be used to make the plastic more pliable. *Wear gloves* when making hose connections to glass tubing.

Suction bulbs should be used on all pipettes. A valved type sold as a "PROPIPET" will save fumbling.

*USE CAUTION when combining chemicals found in your laboratory.* This can produce unexpected and unpleasant reactions.

When disposing of any chemical in the sink, *dilute* with plenty of water.

*Store all bottles of hazardous liquids near floor level in ventilated cupboards.*

*Study and learn the right sections of the antidote chart.* You must know first aid for dealing with lab accidents.

HASTE MAKES WASTE (and accidents). Planning saves more time than hurrying *and produces fewer mistakes.*

# SAFETY - ELECTRICAL MAINTENANCE

*Think safe.* Be orderly and use good housekeeping for your safety and the safety of others.

You must be qualified both in experience and general knowledge to perform your particular job.

Study your job carefully to find the hazards and see that all necessary safeguards and safety devices are provided for safe working conditions.

Examine all safety devices *before you use them* to be sure that they are in good condition.

In all cases where work is being performed on or close to live conductors or equipment, at least two men must work together. When it is necessary for one to leave, *the other workman shall not continue the work until the first man returns.*

Think about the results of each action. There is no reason for you to take chances that will endanger yourself and others.

Satisfy yourself that you are working under safe conditions. *Do not* rely on others.

Wear close fitting clothing. Keep sleeves rolled down. Avoid wearing unnecessary articles while working on or close to live circuits or apparatus.

*Use only approved types* of rubber or leather gloves.

*Protect yourself* by placing an insulated medium between you and the ground or the grounded apparatus. Keep any part of your body from providing a path for electrical current when working on conductors or apparatus that may be energized.

*Use rubber mats* when working on any electrical control panel or switch and disconnect boxes.

VENTILATION

All areas where solvents or other compounds are used and stored must be well ventilated. The working area must be designed and constructed for the safety and convenience of the worker and for his efficient production. The ventilation should be by mechanical means *with the air intake drawing air from the outside.* In rooms where lime and other dry types of chemicals are used, install dust accumulators in the air discharge pipe.

ALUM

Wear protective dust-proof equipment (goggles and nose mask) and proper clothing when handling and storing alum. Avoid skin and nose irritations by using plenty of water when washing and bathing.

AMMONIA

Store cylinders in a cool, dry, *ventilated* place. *Handle with care.* An air pack should be available while handling. In case of leaks, only trained personnel should make repairs. *You must know your first aid if you handle and use this material.*

ACTIVATED CARBON

Store in a dry, fire-proof space. Wear protective, dust-proof equipment (goggles and nose mask) when handling activated carbon. *Do not smoke* while working with or near stored material. Use plenty of water when washing and bathing.

CARBON MONOXIDE

Operate in a well ventilated area when working on engines using gas, gasoline or diesel fuel. Improperly vented gas heaters should be corrected.

LIME

Use protective, dust-proof equipment (goggles and nose mask) while handling lime and use a dust collecting system, if possible. Store in a ventilated, dry area. Use plenty of water when bathing and washing to prevent irritations. Consult a physician if irritation becomes severe.

SODA ASH

Handle soda ash as described for lime. See above.

## SOLVENTS

Be careful when using solvents in confined areas. The area should be well ventilated. Clean solvents from skin to prevent irritations.

## SAFETY PRACTICES - CHEMICAL HANDLING

*The Industrial Safety Act, Ministry of Labour, states that the employer is responsible for providing the necessary protective equipment and clothing for handling dangerous materials. It is the responsibility of the employee, both to his employer and to himself, to use and maintain them.*

Eyewash fountains and deluge showers must be located within fifteen (15) feet of the entrance to any chemical handling area. Plenty of water should be available for washing up after handling chemicals. Protective clothing should be washed after use.

The mechanical venting systems of storage and chemical dispensing rooms must keep the air reasonably dust free. The exhaust from the ventilation system for dry chemicals should be through a dust accumulator. *Operate exhaust fans when handling any chemical whether liquid or dry.*

*Wear rubber boots, apron, gloves and eye shield or goggles when handling liquids. Wear nose and mouth filter masks and goggles when handling dry chemicals.*

## BUILDING MAINTENANCE

Periodic inspections are necessary to eliminate hazards (fire safeguards, etc.). Suggested repairs for safety should receive immediate attention. Floors, hall-

ways and stairways should always be well lighted, clean, orderly and free from oil, dirt and debris. Immediate repairs of hazardous electrical outlets and fixtures should be routine. Adequate sanitary facilities for employees must be provided. Hand-rails on steps and stairways should always be provided and used. *Good housekeeping must be maintained.*

## FIRE PROTECTION

*Good housekeeping is the basis for fire prevention.* Inspections should be made periodically and correction of fire hazards should be made as soon as possible. Consult local fire departments for recommendations.

## HAND TOOLS

Hand tools are the cause of many accidents and injuries when improperly used and in unsafe condition. Therefore, use the right tool for the right job in the right way. Use protective safety equipment where there is a job hazard. Keep the work area clear of hazards, with plenty of working space for solid footing. Tools should be in good condition and used for the purpose for which they were intended.

## PORTABLE AND POWER TOOLS

All equipment should be grounded. Check wiring and equipment regularly for defects. Be very careful when using equipment in wet areas. Use protective safety equipment when operating grinders, buffers, or other tools when there is danger of flying materials.

## TOOLS AND MACHINES

Use protective equipment when operating power equipment if there is any chance of flying objects or other injuries. Inspect all tools and equipment for safe operation. Necessary repairs or replacements should be made immediately. *Repair power tools and machinery only when the equipment is turned off.*

## WELDING

Use the proper protective equipment at all times. Check for fire hazards before cutting or welding in areas of inflammable or explosive mixtures. *Only authorized personnel should operate welding equipment.*

## INSPECTIONS OF TOOLS AND EQUIPMENT

Periodic inspections should be made of tools and equipment so that those that are broken or worn out may be

replaced. *Report worn or broken equipment* and be sure they are replaced or repaired as soon as possible.

## LADDERS

Ladders should be inspected periodically and maintained in good order. *Use safety belts* when awkward positions are necessary for the work. *Do not use metal ladders for electrical work.*

## LIFTING

Always lift with the leg muscles instead of the back and be sure your footing is secure. Bend your knees and keep your back straight. Don't turn or twist your body when lifting. Get help if load is too heavy or awkward to handle. Use mechanical device for lifting wherever possible.

## SANITATION

Washrooms, toilets, locker rooms, drinking fountains and showers that are clean, ventilated and adequately built are good for employee morale. Clean drinking water and paper cups should be available at each plant, especially if the employees are exposed to skin irritant materials.

## STOREROOMS

Good housekeeping must be maintained at all times. Space should be well arranged to permit proper storage, handling and movement of materials. Inspections should be made regularly for fire hazards. Fire extinguishers should be in good order and easily accessible.

## ELEVATED TANKS AND RESERVOIRS

The ground area surrounding elevated tanks and reservoirs should always be neat, clean and landscaped. Tanks and reservoirs must be kept in good condition. Protective fencing should be provided to keep out unauthorized persons. Ladders should be securely fixed. Use safety belts when working in high or hazardous places. More than one workman should be present for work or inspections. Be careful when operating power equipment to avoid electrical hazards.

## TRENCHING (EXCAVATION - SHORING)

Trenching should be done in accordance with Ministry of Labour Trenching Acts. Work areas should be well defined by barricades and traffic safety cones for the protection of the worker and the public. Proper tools and equipment should be available for the job.

Workmen should use the correct protective safety equipment (safety hats, goggles, foot guards, shields, etc.). Inspect trenches for hazards; check for possible cave-ins, projections inside trench, housekeeping, etc. Equipment should be operated by authorized and qualified workmen only.

Since most serious injuries occur in the field, extra precautions should be taken to ensure that job conditions are safe for men in the trench. *Never take chances* while workmen are in the trench. Proper shoring and bracing always pays.

## BARRICADES AND TRAFFIC CONTROL

An adequate and safe work area must be protected. Sufficient traffic cones and barricades should always be carried by crews assigned to construction or maintenance work in streets. Paint barricades bright, visible colours and keep them in good condition. Be sure warning signs, flags, flares are adequate and in positions where they can be easily seen.

## TRUCKS AND EQUIPMENT

Routine inspections of trucks and equipment should be made. Any need for repairs should be reported and acted on as soon as possible. Only qualified and licensed operators should be permitted to use and operate vehicles and equipment. Never permit riders on trucks or other

equipment when it is hazardous. Check electrical and any other hazards constantly when moving heavy equipment. All trucks should be equipped with first aid kits, fire extinguishers, and flares.

## WORKING AREA

*The Ministry of Labour requires a 2 1/2 lb. fire extinguisher be fastened to the welding truck.* A safe working area must be provided for efficient work. In the field, traffic should be controlled by the use of traffic cones, barricades, flags, etc., to protect the workmen as well as the public. In the material yard and storerooms, good housekeeping and properly planned storage and work areas must be provided for safe working practices. Shops, plants and offices should be planned for the most efficient production.

## A SAFETY PRACTICE PROGRAM

*Before starting a safety program, the full co-operation and active support of management is needed.* One person in the utility organization must be responsible for the program. In a small water works system, that person may be the superintendent, while in a larger organization, another person who can devote part or full time to the job can be appointed.

The next step in setting up the program is to provide for:

(1) keeping injury records;

(2) locating the hazards;

(3) making equipment, plant arrangements and working methods safe;

(4) getting employees interested in safety; and

(5) controlling work habits.

## INJURY RECORDS

The keeping of injury records is basic to a safety program. With complete records, the program is given direction and is sure of success. The records should be kept brief but must contain all pertinent data. The forms should cover such items as:

(1) accident report,

(2) description of accident,

(3) physician's statement,

(4) corrective action taken, and

(5) accident analysis chart.

## LOCATING THE HAZARDS

The person responsible for the safety program should be constantly on the alert for hazards which may cause an injury to an employee. One of the best methods of attacking

this problem is to search the records for the conditions and situations that have produced injuries. Records like this show the need for a corrective program.

Many other sources of information on hazardous conditions are available. These include safety manuals, insurance company brochures, etc. They should be used freely and frequently.

## EQUIPMENT, PLANT ARRANGEMENTS, WORKING METHODS

Nothing prevents an accident as effectively as the elimination of the cause. To preach safety while permitting unsafe conditions will discourage the cooperation required from employees. Only when safety is integrated with the job are workers convinced that the man responsible for safety wants to prevent accidents.

SUBJECT:

BASIC WATER
TREATMENT OPERATION

TOPIC: 9

PRACTICAL MATHEMATICS

## OBJECTIVES:

The learner will be able to:

1. Review basics such as addition subtraction, multiplication, division, fractions, decimal, percent and perform basic calculations.

2. Apply the above calculations to practical, everyday use as required on the job.

# PRACTICAL MATHEMATICS

This topic is concerned with practical mathematics. But, before one can solve the problems related to dosages, pumpages, retention times, flow rates etc., he must be able to understand certain fundamental mathematics. This initially will deal briefly with simple mathematics and with certain rules and concepts, which if used will make mathematics easier to understand and to perform.

Mathematics is the science of calculation of quantities and is used to describe as a group the three basic sciences - arithmetic, algebra and geometry.

Arithmetic is the study of numbers and the use of numbers to count, describe and calculate quantities. It includes the simple mechanical process of addition, subtraction, multiplication and division.

Geometry is the study of the magnitudes of space, such as lines, surfaces and planes.

Algebra uses symbols and equations to describe the relation between quantities and to determine solutions to problems.

## ARITHMETIC

Arithmetic will be discussed under the following headings:

addition
subtraction
multiplication
division
fractions
decimals
percent

Addition

Probably the only rule to remember in adding numbers which do not have the same number of digits is to line them up starting from the right-hand side.

The symbol for adding is +

Example:

Add 6,404; 28; 732

$$\begin{array}{r} 6{,}404 \\ 28 \\ \underline{732} \\ 7{,}164 \end{array}$$

Subtraction

The same basic rules which apply to addition apply to subtraction.

The symbol for subtraction is -

Example:

Subtract 828 from 4,272

$$\begin{array}{r} 4{,}272 \\ \underline{-\ 828} \\ 3{,}444 \end{array}$$

Multiplication

Multiplication is the process of repeating or adding a given number a certain number of times. The number which is being multiplied is called the multiplicand; the number by which it is multiplied is called the multiplier; and the result is termed the product.

The symbol for multiplication is x

Example:

Multiply 6,785 by 14

```
  6,785  (multiplicand)
   x 14  (multiplier)
  27140
  6785
  94990  (product)
```

Division

Division is simply the process of finding how many times one number or quantity is contained in another. The number which is being divided is called the dividend; the number which it is divided by is called the divisor; and the resultant number is the quotient. Quite often there is also a remainder.

The symbol for division is ÷

Example:

Divide 1,752 by 12

```
     146
 12/1752
    12xx
     55
     48
      72
      72
       0 - no remainder
```

Divide 18,473 by 68

```
               271    (quotient)
(divisor) 68/18473    (dividend)
             136xx
              487
              476
               113
                68
                45    (remainder)
```

## Fractions

In many cases it is impossible to express a quantity as a whole number, and we must use fractional numbers such as 1/8, 1/4, 2/3 etc. Difficulty is often experienced in doing minor calculations with fractions. A brief review of the calculations involved in the addition, subtraction, multiplication and division of fractions is presented.

The upper number in a fraction is called the numerator, the lower is called the denominator.

### (1) Adding Fractions

Before fractions may be added they must all have a common denominator. To get a common denominator, find the smallest number into which all of the denominators will divide. Having obtained this number, multiply the numerator and denominator of each fraction by the number of times its denominator divides into the common denominator.

Fractions should always be reduced to their simplest form.

Example:

Add $\frac{3}{8}$, $\frac{1}{4}$ and $\frac{5}{16}$

By inspection the lowest number into which each of the denominators will divide is 16, and this is the common denominator. Now 8 will divide into 16 twice, and multiplying the numerator and denominator by 2, the fraction now becomes 6/16. Similarly, 1/4 becomes 4/16 and we can now add because they all have a common denominator.

$$\frac{6}{16} + \frac{4}{16} + \frac{5}{16} = \frac{15}{16}$$

Often a whole number will contain a fraction, and before calculations may be made the number should be changed to a fraction only.

Example:

Add $\frac{1}{8}$ and $5\ \frac{3}{4}$

The number 5 3/4 is changed to a fraction by multiplying the denominator by the whole-number portion and adding the numerator, that is, 4 times 5 plus 3, and the number becomes 23/4.

We now have:

$$\frac{1}{8} + \frac{23}{4}$$

Changing to a common denominator of 8:

$$\frac{1}{8} + \frac{46}{8} = \frac{47}{8} \text{ or } 5\ \frac{7}{8}$$

(2) Subtracting Fractions

The rules for subtracting fractions are similar to those for adding - there must be a common denominator.

Example:

Subtract $\frac{3}{16}$ from $\frac{8}{32}$

$$\frac{8}{32} - \frac{3}{16}$$

$$= \frac{8}{32} - \frac{6}{32} = \frac{2}{32} \quad \text{or} \quad \frac{1}{16}$$

(3) Multiplying Fractions

It is not necessary to change simple fractions to a common denominator before multiplying. Simply miltiply the two numerators and the two denominators together.

Example:

Multiply $\frac{3}{4}$ by $\frac{2}{3}$

$$\frac{3}{4} \times \frac{2}{3}$$

$$= \frac{3 \times 2}{4 \times 3} = \frac{6}{12} \text{ or } \frac{1}{2}$$

When one of the numbers to be multiplied contains a whole number and a fraction it must be changed to a simple fracti before multiplying.

Example:

Multiply $\frac{1}{4}$ by $3\frac{5}{8}$

$$\frac{1}{4} \times 3\frac{5}{8}$$

$$= \frac{1}{4} \times \frac{29}{8}$$

$$= \frac{1}{4} \times \frac{29}{8} = \frac{29}{32}$$

(4) Dividing Fractions

To divide one fraction by another the simplest rule to follow is to invert the bottom fraction and multiply.

Example:

Divide $\frac{5}{16}$ by $\frac{3}{4}$

$$= \frac{5}{16} \div \frac{3}{4}$$

$$= \frac{5/16}{3/4}$$

$$= \frac{5}{16} \times \frac{4}{3}$$

$$= \frac{5 \times 4}{16 \times 3} = \frac{20}{48} = \frac{5}{12}$$

Example:

Divide $5\frac{3}{4}$ by $\frac{1}{8}$

$$5\frac{3}{4} \div \frac{1}{8}$$

$$= \frac{5\ 3/4}{1/8}$$

$$= \frac{23/4}{1/8}$$

$$= \frac{23}{4} \times \frac{8}{1}$$

$$= \frac{184}{4} = \frac{46}{1} = 46$$

Decimals

Another method of expressing fractional numbers is by the use of decimals. Decimals express fractions in multiples of 10, that is, tenths, hundredths and thousandths.

$$\frac{1}{10} = 0.1 \qquad \frac{1}{100} = 0.01 \qquad \frac{1}{1000} = 0.001$$

As shown above, a decimal fraction is denoted by a digit with a period in front of it. The value of the decimal depends on the position of the figures with respect to the decimal point. For example, if a decimal is immediately in front of a number it means that the number has been divided by 10.

Example:

$$0.7 = \frac{7}{10}$$

If there is a zero between the number and the decimal it means that the number has been divided by 100.

Example:

$$0.09 = \frac{9}{100}$$

In addition to decimal fractions there are also mixed decimals which are whole numbers with a decimal fraction.

Example:

$$12\ \frac{1}{2} = 12.5$$

(1) Adding Decimals

When adding decimals the numbers must be listed one bel the other with the decimal points in a vertical line.

Example:

Add 31.56, 4.32 and 88.8

$$\begin{array}{r} 31.56 \\ 4.32 \\ 88.80 \\ \hline 124.68 \end{array}$$

(2) Subtracting Decimals

The rules for subtracting decimals are similar to those for adding.

Example:

Subtract 8.4 from 14.73

$$\begin{array}{r} 14.73 \\ -\ 8.40 \\ \hline 6.33 \end{array}$$

Example:

Subtract 9.32 from 17.8

$$\begin{array}{r} 17.80 \\ -\ 9.32 \\ \hline 8.48 \end{array}$$

(3) Multiplying Decimals

This is done in the same way as ordinary multiplying and the decimal point is disregarded during the calculation. Add the total number of digits to the right of the decimal in the two numbers being multiplied and insert the decimal point in the answer

Example:

Multiply 3.55 by 3.2

```
  3.55
   3.2
  ----
   710
 1065
 -----
 11300 or 11.360
```

Since there are a total of three digits to the right of the decimal in the two numbers multiplied, there must be three digits to the right of the decimal in the answer.

(4) Dividing Decimals

Before dividing numbers which contain decimals the decimal in the divisor should be moved a sufficient number of digits to the right to change it to a whole number. Of course, the decimal in the dividend must also be moved a similar number of digits to the right.

Example:

Divide 253.5104 by 3.52

3.52/253.5104 becomes

```
        72.02
352/25351.04
    2464
    ----
     711
     704
     ---
       704
       704
       ---
         0
```

The decimal point in the answer (quotient) is placed directly above the decimal point in the dividend.

To change a fraction to a decimal simply divide the numerator by the denominator.

Example:

Change 1/4 to a decimal

$$
\begin{array}{r}
0.25 \\
4\overline{)1.00} \\
\underline{8}\phantom{0} \\
20 \\
\underline{20} \\
0
\end{array}
$$

Therefore 1/4 = 0.25

## Percent

Percent is a proportion expressed in hundredths and is used to provide a comparison of the whole. For example, one percent represents 1/100 part of the whole.

Example:

A student obtains 75 marks on a test out of a total of 100. What was his percent?

$$\frac{75}{100} \times 100 = 75 \text{ percent}$$

# ALGEBRA

Although the water works operator will not be called upon too often to use algebra, a little understanding of the subject will be helpful.

## Equations

The most commonly encountered item in algebra is the equation, which is simply a statement of equality of two quantities.

Examples:

$$\begin{aligned} 2 + 2 &= 4 \\ 7 - 4 &= 3 \\ a + b &= c \\ 2x &= 10 \text{ etc.} \end{aligned}$$

As long as the same changes are made to both sides of the equation it will remain unchanged. That is, any amount may be added to or subtracted from both sides, or both sides may be multiplied or divided by the same number, and the equation will remain the same.

Example:

If 3a equals 24, what does a equal?

$$3a = 24$$

Dividing both sides of the equation by 3

$$\frac{3a}{3} = \frac{24}{3}$$

$$a = 8$$

Example:

If $\frac{b}{5} = 3$, what does b equal?

$$5 \times \frac{b}{5} = 3 \times 5$$

$$b = 15$$

## Ratio and Proportion

A ratio is a comparison. For example, if one car costs \$6,000 and a second car costs \$2,000, we say that the first car is 3 times as expensive as the second. Expressed mathematically the ratio is 3:1 and the value of the ratio is 3.

A proportion is simply a statement of equality between two ratios. In the case of the two cars the proportion is

$$\frac{6,000}{2,000} = \frac{3}{1} \text{ or } 6,000:2,000 = 3:1$$

In practice, numerous problems are encountered in which one ratio is known and we must find an equal ratio of which only one of the items is known.

Example:

A desk is 6 ft. long and 3 ft. wide. A desk of similar shape is required with one side 8 ft. long. What will the width be?

$$\text{desk one } \frac{L}{W} = \frac{6}{3} = 2$$

$$\text{desk two } \frac{8}{W} = 2$$

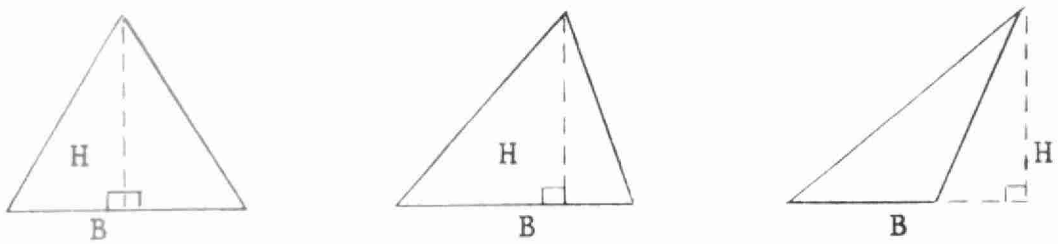
$$\text{Therefore } W = 4$$

GEOMETRY

A water works operator is often called upon to figure out areas and volumes. The types of figures which he is most likely to encounter are shown below:

Areas

(1) Triangle

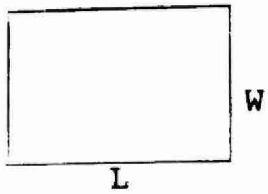



The area of a triangle:

$$A = \frac{1}{2} \text{ base x height}$$

$$= \frac{1}{2} B \times H$$

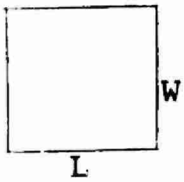
(2) <u>Rectangle</u>




The area of a rectangle:

$$A = L \times W$$

(3) <u>Square</u>

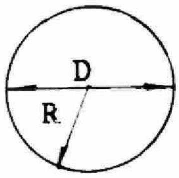



The area of a square:

$$A = L \times W$$
$$\text{but } L = W$$

Therefore $A = L^2$

(4) <u>Circle</u>



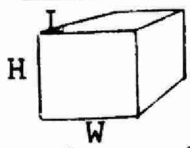

D = diameter
R = radius = 1/2D
C = circumference
$\pi$ = 3.14

The area of a circle:

$$A = \pi R^2 \quad \text{or} \quad \frac{\pi D^2}{4}$$

<u>Volumes</u>

(1) <u>Cube</u>

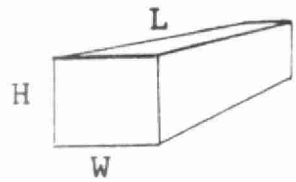



all three sides equal
L = W = H

The volume of a cube:

$$V = L \times W \times H = L^3$$

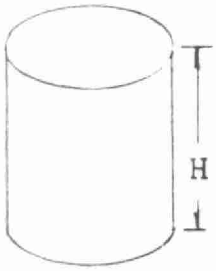
(2) <u>Rectangular Solid</u>




The volume of a rectangular solid:

$$V = L \times W \times H$$

(3) <u>Cylinder</u>




The volume of a cylinder:

$$V = \frac{\pi D^2}{4} \times H$$

## TABLE 10-1

### BRITISH SYSTEM

#### Linear Measure

1 foot = 12 inches
1 yard = 3 feet
1 rod = 5 1/2 yards
1 mile = 1,760 yards
1 mile = 5,280 feet

#### Square Measure

1 square foot = 144 square inches
1 square yard = 9 square feet
1 acre = 160 square rods
1 square mile = 640 acres
1 acre = 43,560 square feet

#### Cubic Measure

1 cubic foot = 1,728 cubic inches
1 cubic yard = 27 cubic feet

#### Weight

1 pound = 16 ounces
1 ton = 2,000 pounds
1 pound = 7,000 grains

#### Liquid Measure

1 quart = 2 pints
1 gallon = 4 quarts

### METRIC SYSTEM

#### Linear Measure

1 centimeter = 10 millimeters
1 meter = 100 centimeters
1 kilometer = 1,000 meters

#### Square Measure

1 sq. centimeter = 100 sq. mm
1 sq. meter = 1,000 sq. centimete
1 sq. kilometer = 1,000,000 sq. meters

#### Cubic Measure

1 cubic centimeter = 1,000 cu. mm
1 cubic meter = 1,000 litres

#### Metric Weight

1 gram = 1,000 milligrams
1 kilogram = 1,000 grams

The lecture given in the basic course dealt primarily with the fundamentals of mathematics. With this knowledge of fundamentals we may now go on to apply what was discussed during the basic lecture to the every day operation of water works systems.

## Conversion Factors

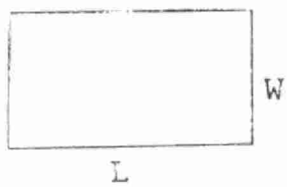
A complete table of conversion factors has been provided in the basic mathematics lecture. The common conversion factors are listed below for handy reference.

| | | |
|---|---|---|
| 1 cubic foot | = | 62.4 pounds |
| 1 cubic foot | = | 6.24 gallons |
| 1 gallon | = | 10 pounds |
| 1 gallon per minute | = | 1,440 gallons per day |
| 1 cubic foot per second | = | 539,000 gallons per day |
| 1 cubic foot per second | = | 375 gallons per minute |
| 1 grain per gallon | = | 14.3 parts per million |
| 1 Imperial gallon | = | 1.2 US gallons |
| 1 US gallon | = | 0.833 Imperial gallons |
| 1 pound per square inch | = | 2.31 feet of head |

## Example 1

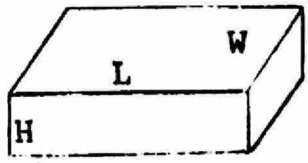
A rectangle is 7 inches long and 4 inches wide. What is its area?

$$\begin{aligned} A &= L \times W \\ &= 7 \times 4 \\ &= 28 \text{ square inches} \end{aligned}$$




If the rectangle above were to cover a box 3 inches deep, what would the volume of the box be?

$$V = L \times W \times H$$
$$= 7 \times 4 \times 3$$
$$= 84 \text{ cubic inches}$$




Example 2

A cylindrical tank 5 feet in diameter is filled with lime slurry to a depth of 11 feet. Assuming it can be drawn down to a level of 1 foot, how many gallons of lime slurry will be drawn off?

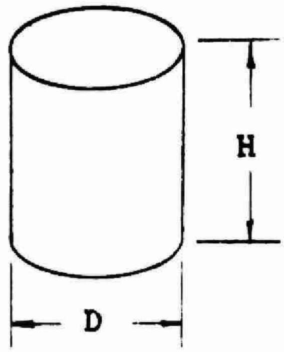
Volume of cylinder

$$= \frac{\pi D^2}{4} \times H \qquad D = \text{diameter}, \quad H = \text{height}$$

$$= \frac{3.14 \times 5^2 \times 10}{4}$$

$$= \frac{3.14 \times 25 \times 10}{4}$$

$$= 196.2 \text{ cubic feet}$$




Since 1 cubic foot = 6.24 gallons, the amount of slurry drawn off

$$= 196.2 \times 6.24$$

$$= 1{,}224 \text{ gallons}$$

Example 3

A sedimentation basin is 100 feet long, 25 feet wide and 10 feet deep. What is its volume in

(a) cubic feet?
(b) gallons?
(c) million gallons?

(a) $V = L \times W \times H$
$= 100 \times 25 \times 10$
$= 25{,}000$ cubic feet

(b) $= 25,000 \times 6.24$
$= 156,000$ gallons

(c) $= \dfrac{156,000}{1,000,000}$
$= 0.156$ million gallons

What would be the volume of water in the same sedimentation basin if it contained 8 feet of water, in

(a) cubic feet?
(b) gallons?
(c) million gallons?

Since the depth of water in the tank is now 8 feet instead of 10 feet the answers become

(a) $\dfrac{8}{10} \times 25,000$
$= 20,000$ cubic feet

(b) $\dfrac{8}{10} \times 156,000$
$= 124,800$ gallons

(c) $\dfrac{8}{10} \times 0.156$
$= 0.1248$
$= 0.125$ million gallons

If the flow-rate through the tank is 500 gallons per minute what is the detention time in hours at the 8-foot depth?

500 gpm $= 500 \times 60$
$= 30,000$ gallons per hour

Volume of tank
$= 124,800$ gallons

Therefore, detention
$= \dfrac{124,800}{30,000}$
$= 4.2$ hours

Example 4

A pump is capable of discharging 400 gallons per minute. What chlorine feed-rate is required to provide a dosage of 2.5 ppm?

$$400 \text{ gpm} = 400 \times 1{,}440 \times 10 \text{ lb of water per day}$$

Weight of chlorine required

$$= \frac{2.5 \times 400 \times 1{,}440 \times 10}{1{,}000{,}000}$$

$$= 14.4 \text{ lb per day}$$

Therefore, chlorine feed-rate required is 14.4 lb per day.

Example 5

A new 12-inch watermain 1,000 feet long is to be disinfected with an intended residual of 50 ppm. Assuming a 10-ppm chlorine demand, how many pounds of chlorine gas are needed?

$$\text{Volume of pipe} = \frac{\pi D^2}{4} \times 1{,}000$$

$$= \frac{3.14 \times 1 \times 1{,}000}{4}$$

$$= 785 \text{ cubic feet}$$

$$\text{Weight of water} = 785 \times 62.4$$

$$= 49{,}000 \text{ lb}$$

Since there is a chlorine demand of 10 ppm, the dosage must be 60 ppm to provide a residual of 50 ppm.

$$\text{Weight of chlorine} = \frac{60 \times 49{,}000}{1{,}000{,}000}$$

$$= 2.93 \text{ lb}$$

If calcium hypochlorite, 70 per cent available chlorine were to be used in the above, how many pounds would be required?

$$\text{Weight of hypochlorite} \times 0.70 = 2.93 \text{ lb}$$

$$\text{Weight of hypochlorite} = \frac{2.93}{0.70}$$

$$= 4.2 \text{ lb}$$

Example 6

A total of 150 pounds of alum was added to a mixing basin during a 24-hour period. If the total flow during that period was 1.5 million gallons, what was the dosage in

(a) parts per million?
(b) grains per gallon?

(a) $$\frac{150 \times 1{,}000{,}000}{1{,}500{,}000 \times 10} = 10 \text{ ppm}$$

(b) $$10 \text{ ppm} = \frac{10}{14.3} \text{ gpg}$$
$$= 0.7 \text{ gpg}$$

Example 7

The recommended dosage of Calgon for the control of "red-water" problems is 2 ppm Calgon for each 1 ppm of iron in th raw water. If the iron content in a water is 1.35 ppm and the average daily consumption is 750,000 gallons, how many pounds of Calgon are required per day?

$$\text{Dosage of Calgon} = 2 \times 1.35$$
$$= 2.70 \text{ ppm}$$

$$\text{Daily requirement} = \frac{2.70 \times 750{,}000 \times 10}{1{,}000{,}000}$$

$$= 20.25 \text{ pounds}$$

Example 8

An aeration device at an iron-removal plant is expected to reduce the iron content of the water from 2.3 ppm down to 0.3. If the average daily flow-rate is 100,000 gallons, how many pounds of iron would be removed?

2 ppm are removed

100,000 gallons = 1,000,000 lb

Therefore, $\frac{2 \times 1,000,000}{1,000,000}$

= 2 lb are removed

Example 9

The recommended average rate of flow through rapid sand filters is 2 US gallons per minute per square foot. The average daily flow through a filter having dimensions of 12 feet by 20 feet is 1 mgd (US). Is the filter overloaded?

Area of filter = 12 x 20
= 240 sq ft

1 mgd = $\frac{1,000,000}{1,440}$

= 695 gpm

Filter rate = $\frac{695}{240}$

= 2.9 gpm per sq ft

Therefore it is overloaded

Example 10

The totalizer readings on a meter which times the operation of a pump in hours were 6863 and 6897 at the beginning and end of a pumping period. If the pump is rated at 375 gallons per minute, how many gallons were pumped?

No. of hours of pump operation

$$\begin{array}{r} 6897 \\ -\ \underline{6863} \\ 34 \end{array} \text{ hours}$$

No. of minutes of pumping

$$34 \times 60 = 2{,}040 \text{ minutes}$$

Total pumpage

$$375 \times 2{,}040 = 765{,}000 \text{ gallons}$$

Example 11

The meter readings at a water works at the beginning and end of a 5-day period were 65271 and 65846. If the meter readings represent 1000's of gallons, what was the average daily consumption?

$$\text{Pumpage} = \begin{array}{r} 65{,}846{,}000 \\ -\ \underline{65{,}271{,}000} \\ 575{,}000 \end{array} \text{ gallons}$$

$$\text{Average day} = \frac{575{,}000}{5}$$

$$= 115{,}000 \text{ gallons}$$

If there were 250 homes on the system, and assuming each used the same amount, how much did it cost each home-owner if the water sold at the rate of 41¢ per thousand gallons?

$$\text{Usage per home-owner} = \frac{115{,}000}{250}$$

$$= 460 \text{ gallons}$$

$$\text{Cost} = 0.460 \times 0.41$$
$$= 19¢ \text{ per home-owner}$$

Example 12

If the water level in an elevated storage tank is 165 feet above the adjacent pumphouse pressure gauge, what should the gauge read in pounds per square inch?

1 pound per square inch = 2.31 feet

Therefore, gauge reading

$$= \frac{165}{2.31}$$

$$= 71.4 \text{ psi}$$

Example 13

The velocity of the water moving in a 12-inch pipe is 3 feet per second. What is the flow in

(a) cubic feet per second?
(b) gallons per minute?

The flow is equal to the velocity times the area of the pipe

$$Q = VA$$
$$V = 3 \text{ fps}$$
$$A = \frac{\pi D^2}{4} \qquad D = 12 \text{ inches} = 1 \text{ foot}$$
$$= \frac{3.14 \times 1^2}{4}$$
$$= 0.785 \text{ square feet}$$

(a) $Q = 3 \times 0.785$
$= 2.355$ cubic feet per second

$$
\begin{aligned}
\text{(b)} \quad Q &= 2.355 \times 375 \\
&= 883 \text{ gpm}
\end{aligned}
$$

Example 14

A solution is made up of 10 pounds of chlorine, 30 pounds of water and 10 pounds of lime. What is the per cent of each of the three components in the mixture?

The total weight of the mixture is 50 pounds.

$$\text{Per cent of chlorine} = \frac{10}{50} \times 100 = 20$$

$$\text{Per cent of water} = \frac{30}{50} \times 100 = 60$$

$$\text{Per cent of lime} = \frac{10}{50} \times 100 = \underline{20}$$

$$\text{Total} \quad 100$$

# MATHEMATICS REVIEW

1. Add:

   (1) $\frac{1}{8}$, $\frac{3}{16}$ and $\frac{1}{4}$ (2) 5.68, 0.233 and 75.2

   (3) $2\frac{1}{4}$, $3\frac{1}{2}$ and $7\frac{3}{8}$

2. Multiply:

   (1) $3\frac{3}{8}$ by $\frac{3}{5}$ (2) 68.3 by 6.23

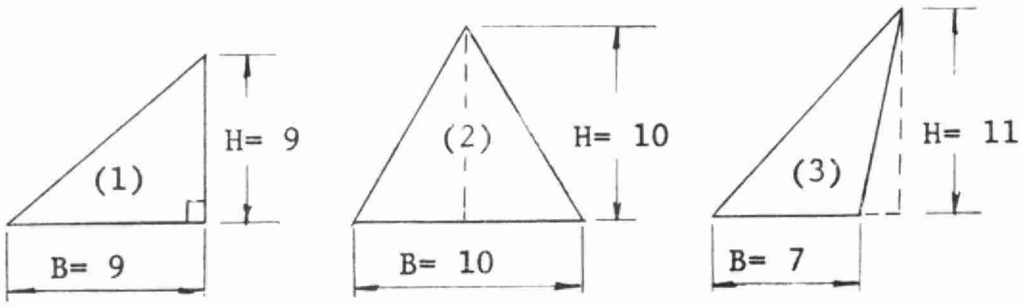
   (3) 0.023 by 38.7

3. Divide:

   (1) $\frac{5}{6}$ by $\frac{2}{3}$ (2) 425.509 by 68.3

   (3) 5481 by 63

4. Find the area of the following:




Note: In triangle (2) the two angles at the base and the two sides are equal. All measurements are in feet.

5. What is the area of a rectangle whose dimensions are 24 inches by 12 inches

   (a) in square inches?
   (b) in square feet?

6. What is the volume of a tank whose dimensions are 30 feet by 15 feet by 10 feet deep

   (a) in cubic feet?
   (b) in gallons?

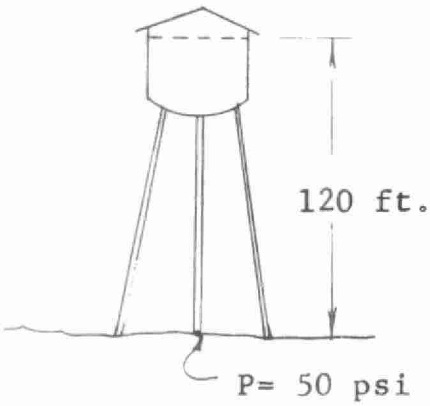
7. What is the area, in square feet, of a circle which has a diameter of 5 feet?

8. Find the volume of a cylinder which has a diameter of 6 feet and a height of 11 feet

   (a) in cubic feet
   (b) in gallons.

9. A tank which has a capacity of 60 gallons contains 25 gallons of water, 15 gallons of liquid alum and 20 gallons of lime slurry. What per cent of the total does each of the three substances in the tank represent?

10. The water pressure at the bottom of an elevated storage tank is 50 pounds per square inch (psi). If the tank has a height of 120 feet is there sufficient pressure to fill it?




11. How many pounds of gas chlorine are required to disinfect 1,500 feet of 8-inch-diameter watermain if the required dosage is 50 parts per million?

12. If the chlorine compound used in question 11 has only 70 per cent available chlorine how many pounds are required?

13. A rectangular settling tank has a volume of 6,000 cubic feet. How long would it take to fill the tank with a pump rated at 750 gallons per minute?

14. The velocity of water in an 8-inch-diameter pipe is 1.5 feet per second. What is the flow

    (a) in cubic feet per second?
    (b) in gallons per minute?

15. A pump has a capacity of 500 gallons per minute. If the discharge is to receive a chlorine dosage of 0.5 parts per million what must the capacity of the chlorinator be in pounds per day?

SUBJECT:

BASIC WATER TREATMENT OPERATION

TOPIC: 10

RECORDS

OBJECTIVES:

Trainee will be able to:

1. State one of the main reasons for maintaining plant flow records;

2. State one method and the reason for maintaining records on the distribution system, i.e., valves, hydrants, booster stations, blow-off valves, etc;

3. List at least 5 entries or observations that should be made on the daily operating log sheets.

# RECORDS

The maintenance of records, or the collecting of figures, can be a time consuming task; a thing which someone thinks we should do, but for which many of us can see little purpose. Still, our very existence is one record after another, maintained mentally, to be forgotten as soon as the data is received, or kept in permanent form for future reference.

*Records are essential for planning future expansions.* We all keep them and use them constantly: bank books, for instance.

Records should be permanent. Therefore, *ordinary lead pencils must not be used.* Lead pencil notations smudge and can be erased or changed too easily. Always use ink or indelible pencil. A hard-back ledger is better for daily records than a scratch pad. Filing cabinets are essential for lab analyses and any other loose records.

## OPERATIONAL RECORDS

### Treatment Plant

Records of *treatment plant* operation may include information on filter runs, wash water used, pumps in operation, chemicals used, condition of the raw and treated water,

flows, chemicals on hand and on order, chlorination rates, power consumption, periods of maximum electrical demands, weather observations, and results of laboratory control tests for ensuring adequate treatment of the water delivered by the plant. If your initial supply is from wells, record well drawdowns and rate of aquifer replenishment. If your supply is from streams or lakes, record stream or lake levels.

To set up a system of adequate records, two things are important. First, the form and extent of the records must be carefully planned. Second, a procedure must be established to ensure the continuance of the records selected. This is most important, because a set of operating conditions, if not recorded immediately, can never be accurately reproduced.

However up to date and comprehensive records may be, they are of little value, particularly for use in planning plant expansion, if the figures do not accurately represent what is happening at the plant. Most of the data recorded is not entirely independent, so they can be checked against each other. All flow metering should be checked regularly for accuracy. If a tank is emptied for repairs, the indicated total flow required to fill the tank should be checked against a calculated volume of the tank.

## Distribution Systems

Strict procedures should be followed in relaying information on the operation and maintenance of *distribution*

*systems* to the plant operator. A large scale comprehensive map is necessary to show all mains, their sizes and types, valves, hydrants, streets, reservoirs, elevated tanks, wells, booster stations and emergency interconnections with other systems, as well as blowoffs, air release valves and normally closed gate valves, if possible.

The original map should be carefully stored and copies issued to operating personnel for their use. In the case of smaller systems or where the map is not too large, a copy should be displayed on the wall in the operations centre. As the map must include the entire system, the scale may be too small to show the required detail. Therefore, to have an adequate record, it will probably be necessary to divide the map into sections on separate sheets, using an adequate scale to show the required details. Sectional maps must be accurately scaled so that adjoining sheets will line up. Information on sectional easements, street names and widths, mains, their sizes and locations, material, year installed, hydrants, their types and classes, details relating to valves, service lines including sizes and locations, and all other information relating to the section of the system under study should be recorded. In other words, the section map is a magnified part of the major system map which enables you to read the fine print. In large distribution systems, it is often advisable to enlarge or divide section maps for works foremen assigned to particularly congested areas. In preparing a section map it may not be possible to obtain all the desired information in an economically short time. This

information may be omitted until it can be obtained without undue expense.

VALVE RECORDS

Sectional maps are among the most important of all distribution system records. Supplements for field crew use are *valve records.* These are lists of all gate valves with their locations, functions, and operation. Data cover each valve number, size, make, class, number of turns to open, direction of turns to open, street location, distance and direction from the principal street line or curb and intersection, or other information to help locate the correct valve quickly.

STATISTICAL RECORDS

Most of the information accumulated on daily operating log sheets is *statistical,* dealing with:

- hourly flows
- maximum and minimum daily flows
- total flows
- power consumption
- quantities of chemicals used
- water conditions
- periods and times of maximum power demands
- hours of pump operation

and many other factors to be compared with past records and used for forecasting future operating conditions. Close comparison of these figures can be interesting. For instance, collation of total flows can indicate to main crews that a leak has occurred in the distribution system. Records of operating costs, total flows and plant capacity may influence the addition of meters in the system. Periods of maximum power demand will give you clues as to when to start auxiliary mechanically driven pumping units, thus reducing monthly power bills and plant operating costs. Maximum flows may indicate the necessity for increasing plant capacity or revising plant design.

## ACCOUNTING RECORDS

All *accounting records* may not come under the jurisdiction of the plant operator, but information that includes inventory control, costs of maintenance and time or payroll data does. The payroll records are highly important to the operator. If they are not accurate, and are not submitted to central accounting on time, he will receive complaints. With the development of machine accounting, many of the major accounting records are maintained in the form of punched cards. These can include much information in a small space. Later, they can be used for billing procedures and collection data.

## DAILY LOG BOOK

Another useful record is the *diary* or *daily log book.* Many miscellaneous incidents in plant operation do not fit into the regular records employed, but they should be kept in some type of permanent form and might include:

- occasional numerical data and measurements
- maintenance items, replacement and repairs
- start-ups
- trouble, and various methods tried for correction in start-ups or treatment
- complaints from customers
- visits by officials and their comments
- reports from other agencies (such as the Ministry of Health) on inspections and tests

and similar facts that an operator always appreciates having on hand. This information may be quickly referred to if the daily summary sheet of operation contains a cross reference. Knowledge of the date of an occurrence, even without further detail, is often helpful.

The records you keep will depend on the type of plant you operate, the amount and category of information you need to answer enquiries, and any information that will help you to operate the plant efficiently and economically. *The important items to remember in record keeping are accuracy and continuity.*

**SUBJECT:**

BASIC WATER TREATMENT OPERATION

**TOPIC:** 11

CARE, MAINTENANCE & OPERATION OF A DISTRIBUTION SYSTEM

## OBJECTIVES:

Trainee will be able to:

1. Recognize 5 problems common to neglected distribution systems;

2. Describe procedures for disinfection of new works as outlined in 65-W-4;

3. Describe routine maintenance required on:

   Valves
   Hydrants
   Reservoirs

4. Describe 5 steps to take when adverse distribution system samples are received;

5. Describe 2 methods of leak detection in distribution systems;

6. State the 2 common types of cross connections and describe 4 methods of prevention;

7. Indicate the best method of pipe thawing and state 2 reasons.

CARE, MAINTENANCE & OPERATION OF A WATER DISTRIBUTION SYSTEM

## INTRODUCTION

Without an adequate maintenance programme, even the best installed systems will deteriorate.

Problems common to neglected systems include:

1) Fire hydrants that will not produce the necessary volumes and pressures

2) Undesirable taste or odours within the distribution system caused by
   - (a) dead water - dead ending mains
   - (b) rerouting of water - change of flow direction
   - (c) lack of a routine flushing program

3) Leak repair work or maintenance requiring shut off

4) Reduced water flow caused by incrustations lining the mains

5) Frequent water main breaks as a result of freezing lines and services.

## NEW DISTRIBUTION SYSTEMS

- The Ministry requirements for disinfection are detailed in Bulletin 65-W-4

- AWWA also has recommended procedures for disinfection

- Chlorination of all new works is required; however, it is effective only in sterilizing the surfaces. It does not remove foreign material (occasionally animal or foreign matter is left in the main) during construction

- The practice of eliminating "pigging" or swabbing the mains to save money is a foolish risk.

- During construction, new lines must be swabbed or pigged. (Although the swab will not move a wood block, the loss of two or three swabs may indicate trouble).

*All main repair work must be adequately disinfected to AWWA standards.* No one will object to the generous use of chlorine when disinfecting mains.

*Valves*

- Know the location and operating condition of every valve in the system. (This should be detailed on a map of the municipality.)

- Very little can be done to maintain buried valves without excavation. (All valves should operate in the same direction if possible to avoid damage when an overeager helper tries to open the valve in the wrong direction).

- All valves should be closed and opened at least once a year. Since gate valves are constructed of different metals, corrosion can take place on the moving faces unless they are routinely flushed by regular operation. Valve blockages can sometimes be flushed by partially closing the valve, closing an adjacent main valve, and opening a hydrant between the two.

- Valve boxes must be adequately protected from vandalism.

- All valves and valve boxes adjacent to or part of construction projects must be inspected regularly during the work to ensure that all conditions are satisfactory.

*Hydrants*

- Hydrants are frequently the only portion of the distribution system actually seen by the public and therefore should be kept in good condition and painted.

- Although it may be desirable to use hydrants only for fire fighting, other uses might be allowed for a nominal sum or by payment for the water used. An auxiliary valve should be installed on one of the hose nozzles to permit only authorized personnel to operate the hydrant at the start and end of the required period. This prevents damage from improper and repetitive hydrant operation.

- Hydrants should be checked at least twice each year (Spring and Fall).

- Items to check include:
  - Stuffing box
  - Valve
  - Valve seat
  - Barrel (for cracks)
  - Drain parts (if in use)
  - Threads
  - Geared opening mechanism and gaskets

## ROUTINE MAINTENANCE

I *Pipes*

- Proper installation can be the best aid to maintenance. Pipes should be laid by hand on the bottom of undisturbed soil in a trench.

- Main leaks and breaks occur most frequently in the winter when contractions due to cold trouble the system with assistance from:
    - (a) thin pipe walls as a result of corrosion
    - (b) improper bedding allowing pipes to sag
    - (c) metal fatigue from vibration
    - (d) water hammer
    - (e) construction activity adjacent to the piping

- Improper bedding can cause circular breaks in small pipes.

- Larger pipes can develop splits from ring stresses.

How to Repair

1. *Circumferential break* - split sleeves
2. *Longitudinal break* - dewater main and install a new section.

After excavation and repair, back fill well using granular material (3/8" crushed stone)

*Rubber Joints* - make sure to provide adequate blocking or strapping at bends, change of direction points, or at end of line.

II *Hydrants*

- Hydrants should be opened or closed slowly to prevent water hammer in the rest of the distribution system.

- Hydrants should be properly drained to minimize chances of contamination or freezing. In areas where high water table floods the

hydrant barrel, drains should be plugged and the hydrant pumped dry after every use. Routine pumping should be carried out at problem hydrants to ensure that no damage due to freezing takes place. *Antifreeze in the hydrant barrel may enter the water main with a drop in pressure, constituting a potential health hazard. Its use is not recommended.*

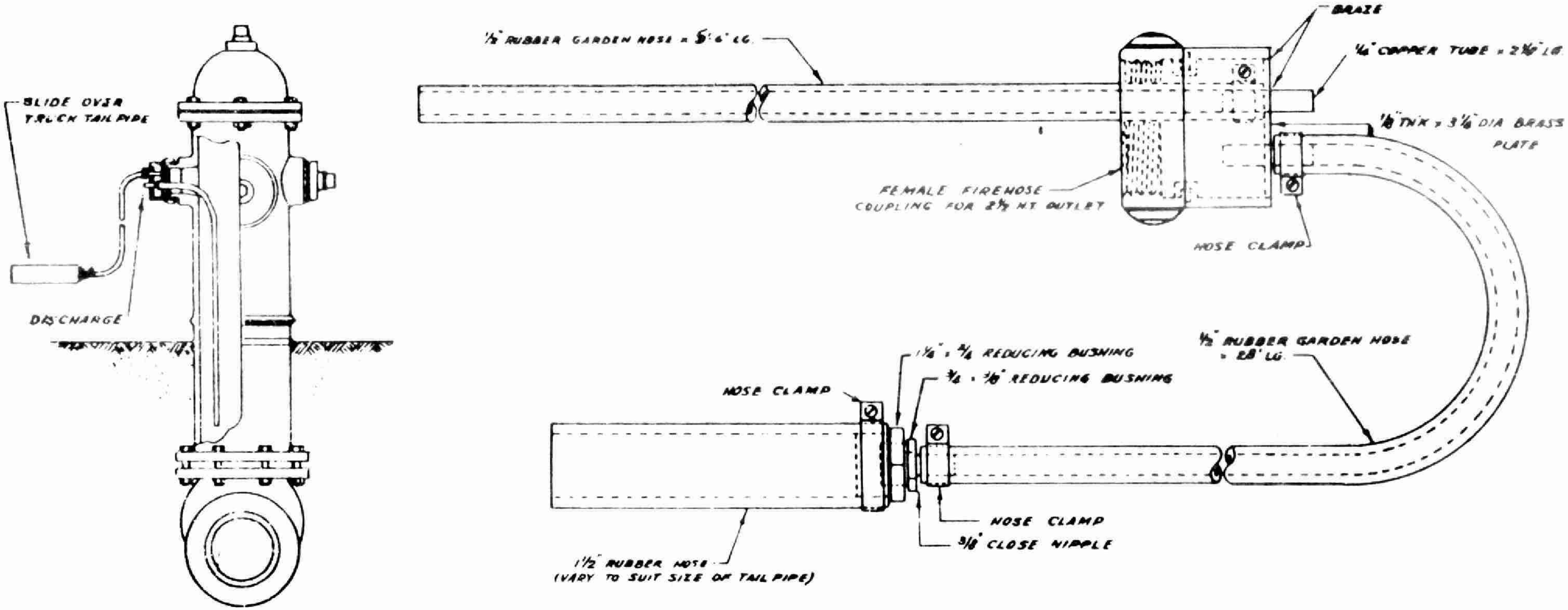
- When self-draining hydrants are in use, hose nozzle caps should not be replaced immediately. Allow the hydrant barrel to drain. (See Figure 11-1 for details of an exhaust powered hydrant pump.)

III *Reservoirs*

- Elevated storage, stand pipes and ground storage require routine inspection and maintenance to ensure they are not the source of water quality problems and excessive leakage.

- Tanks and stand pipes should be drained and inspected each year to ensure that severe corrosion does not proceed to the point of failure. Tanks should be cleaned and painted routinely. *Safety regulations governing work in confined spaces must be met at all times.*

- Ground storage should be emptied and the slime and deposits removed regularly. *The works must be disinfected before being returned to service.*




EXHAUST POWERED HYDRANT PUMP

FIGURE 11-1

PROBLEM SOLVING IN DISTRIBUTION SYSTEMS

1. *Taste, odour and colour problems*

   - A flushing and foam swabbing programme can be of some help in controlling water discolouration.

   - Problems may be generated:

     a) within dead areas where water becomes stagnant and deoxygenated (flat)

     b) when turbidity and iron settle out in the mains

     c) when iron and sulphur bacteria are allowed to build up and cause offensive odours

     d) through internal corrosive action on mains due to aggressive water (low pH)

   - In instances where the flushing and swabbing programme fails to help, techical aid should be called in immediately.

2. *Adverse Bacteriological Sampling*

   - In most instances it will be possible, through intensive resampling, to trace the cause or origin of the problem.

   - Samples must be taken *immediately* after the adverse results are received. The operator has the responsibility of supplying safe water to the public.

What to Do

Inform your MOE Regional Engineer and the local Health Unit *immediately*.

- resample the raw and treated water
- resample the location of the bad sample
- take sample from consumers on either side of bad sample
- stay on top of the problem at all times!
- on-the-spot chlorination may be necessary if internal contamination has taken place. Know where you can lay your hands on such equipment in an emergency.

3. *Leak Detection*

There are two main methods of finding leaks. These may be divided into (a) leaks that you can see, and (b) leaks you can hear. Use your common sense; if you sink up to your ankles in mud in a normally dry section of ground, there must be water somewhere. It should be checked if you have a water main or service nearby. The fact that the surface ground is dry is no proof that you do not have a water leak. Water will find the easiest path to escape and sometimes this path is not the obvious one of bubbling up through the surface. This is particularly true during the winter.

(a) Leaks You Can See

1. Water flowing on the ground.
2. Damp sections of land that don't dry up.
3. A very nice patch of green grass in the middle of a dry lawn.

4. When it is snowing, one section of the ground does not have any snow on it. (The water leaking raises the temperature of the ground slightly and melts the snow.)

In the winter time when the ground is frozen, the water from the leak can travel long distances to find a spot where the frost is not solid. It will then surface at that location.

(b) Leaks You Can Hear

When listening for a leak, try to remember the big leaks are quiet, and the little leaks sound like Niagara Falls. Slight leaks that don't get any bigger can be tolerated; however, little leaks have a habit of washing sand into the leak, wearing the leak larger and eventually causing trouble, so *don't neglect the leaks because they are small.*

There are two methods of listening for leaks. One is to use an ordinary metal rod or stick with an ear cap on one end. You place the end of the rod or stick on any water-carrying pipe and listen. Some people are expert at this simple procedure because they have used it often enough to be able to identify the sound of a leak as opposed to the sound of real water usage. Modern electrical amplifying equipment accomplishes the same result, by allowing more volume. It is often equipped with a meter. The equipment is moved from area to area, usually using hydrants as listening posts, until the area is located where the noise is loudest. It may be necessary to shut off services at curb boxes to limit the water movement within the area under question until the exact location of the leak is established.

The really bad leaks are the ones going into sewers or sand, carrying the water away unnoticed. If you have a bad leak, look for the general area by shutting down the mains. This must be done at night. Such a leak can be suspected when pumpage suddenly increases and doesn't drop below a certain level at night or Sunday as normally expected.

## Repair of Leaks and Breaks

It is important to disinfect all exposed surfaces when repairing leaks and breaks as outlined in Bulletin 65-W-4 and discussed in the chlorination lecture.

## OCCURRENCE OF CROSS CONNECTIONS

The passage of polluted or unsafe water into a water supply system by backflow is known as a *cross connection.*

The occurrence of cross connections is not unique in any specific type of plumbing fixture or on any particular premises. The hazards may exist in homes, in public buildings, or may occur on commercial and industrial premises. Some installations vulnerable to cross connections are: water closets equipped with a flushometer, laboratory sinks, steam tables, water cooled apparatus, or any equipment with a submerged supply.

Two common types of cross connections:

1. Back Flow
2. Secondary Supply Systems

## Prevention of Cross Connection

The enforcement of stringent plumbing regulations, however, can be of great help in avoiding the most common cross connections. The Plumbing Code applying to water supply systems is designed, in part, to ensure that active and potential cross connections do not occur. Much can be done to prevent cross connections by observing the following principles of plumbing: the use of air gaps, the effective installation of back flow preventers, provision for fixture overflow, and the use of indirect supplies.

Whenever possible, there must be an air gap between the supply outlet and the flood level rim of the fixture. Unless a back flow preventer is properly installed in the distributing pipe, the orifice of the faucet or spout must be located so that the air gap complies with the plumbing regulations of the Province of Ontario.

## PIPE THAWING

### *Incidents of Freezing Problems*

Since freeze-ups occur in most municipal systems in Ontario, the services of thawing crews are required during the winter months. Apparently, as long as a favourable balance of heat is maintained in the pipeline, freezing conditions will not develop.

Frozen services are more common than frozen mains. Less water and longer periods of no motion can cause this. Insulation protects pipes from freezing. Another protection is to bury the pipes below the frost line.

*Methods Used in Thawing Watermains*

Frozen watermains require the application of enough heat to melt the ice and snow, permitting the water to resume flowing. Many methods have been used:

1. Digging down to the pipe and building a fire in the trench over it.

2. Using gasoline or torches.

3. Wrapping the pipe in rags and pouring hot water on it.

4. Using steam.

5. The use of electricity.

Except for the use of electricity, these measures involve considerable time and inconvenience, and are often messy. Pipes may be split from extreme heat when steam or open fire are used.

*Electrical Thawing of Watermains and Services*

The passage of electrical current through a conductor, whether it is a wire or a pipeline, encounters resistance. *This resistance creates heat,* the intensity depending upon the characteristics of the conductor. This is the principle behind the electrical thawing of pipes. The low melting point of lead indicates the danger of melting lead surface pipes with high currents. Iron lines heat most readily, while copper heats slowly. Whenever lead goose-necks are used, low currents should be employed.

Thawing Procedure

1. Locate the frozen section of pipe.

2. Include the frozen section in an electrical circuit by connecting cables from the source of energy to the closest convenient points in the piping system (hydrants, curb service boxes, etc., or, for service connections, exposed pipes in the house and the service shut-off).

3. Ensure that good electrical connections are made. Remove rough scale at the point where the clamp is to be fastened to the pipe or arcing may cut holes in the pipe.

4. If a house service is involved, remove the water meter from the circuit to break the connection between the service pipe and the house piping.

5. Remove the ground clamp from the water pipe to prevent stray electrical currents getting into the neutral wire and wiring system of the house.

6. Proceed with thawing.

Removal of the meter alone or disconnection of the ground clamp alone is not enough to keep the current from feeding into the house wiring circuits. *Use caution.* Underground contact of metal pipes or some other circuit may occur.

Some Do's and Don't's on Thawing Frozen Watermains

1. Use the least current possible to do the job. The lower the voltage, the less the chance of injury to persons or property, including piping.

2. Avoid connections which might waste current and prolong thawing. Use only generator sets equipped with meters to determine the exact amount of current used. If the meter does not indicate a current flow, this may be caused by poor connections or bad joints in the pipe, or connections which have been made to different pipe systems. *Make sure that the frozen length of pipe is included in the circuit.*

3. Avoid the possibility of shorts or ground. Current may be fed back through gas services by the water heater. *No gas pipes or furnace support wires should be in contact with the pipe being thawed.* Radio ground wiring should be detached. Heat may be detected by placing a hand on the meter couplings. To play safe, the main switch should be disconnected.

4. Make certain of the pipe material in use and make allowances in the current applied.

5. Make sure the wires from the energy sources are adequate and that a good electrical contact is made. Scraping the pipe surface may be necessary. Distance between the connections should be as short as possible and limited to the frozen piece of pipe.

6. *Open the pipe before thawing.* This will let you know if water is beginning to flow. It also avoids the possibility of steam pressure developing and doing more damage than the frozen line.

# GLOSSARY

*The following definitions are intended as aids in the study of this manual, and define the terms only as they are used in the manual.*

DO NOT use this glossary in place of a dictionary.

ABS: Abbreviation for Sodium alkyl benzene sulfonate.

ADSORB: To hold on the surface; stick on.

ADVERSE: Acting against; so opposed as to cause often harmful interference.

AIR GAP: The distance between the lowest opening of a pipe supplying water to a tank or plumbing fixture and the flood-level rim of the receptacle.

ALGAE: Tiny plants, usually living in water and often green in colour.

ALGICIDE: Anything applied to kill or control algae.

ALTERNATE: Substitute; to change from one to another repeatedly.

ALUM: Chemical Aluminum sulfate; used in sewage treatment to remove phosphorus. Also used in water treatment as a coagulant.

ANALYSIS: The examination of a sample to determine its components or ingredients.

ANIONIC: Relating to negatively charged ions.

APPRECIABLE: Measurable, Perceptible; enough to be seen, smelled, heard, felt, or tasted.

AQUIFER: Porous, water-bearing formation of rock, sand, or gravel.

ARTESIAN AQUIFER: Aquifer surrounded by less permeable formations.

ARBITRARY: Depending on choice or judgement.

BACKFLOW: The backing up of water through a conduit or channel in the direction that is opposite to normal flow.

BACKWASH: The method used to clean filter media by reversing the water flow.

BEAKER: A deep, wide-mouthed cup used in laboratory work.

BEDDING: The earth or other materials on which a pipe or conduit is supported.

BEDROCK: The solid rock underlying the loose material such as soil and rocks on the surface of the earth.

BOOSTER STATION: A pumping station in a water distribution system, used to increase the pressure in the mains on the discharge side of the pumps.

CALIBRATION: The process or state of indicating values or positions by measuring against a standard.

CARBONACEOUS: Made of, or containing carbon.

CHARACTERISTICS: Different qualities or ingredients.

CHLORINE DEMAND: The difference between the amount of chlorine added to a water or wastewater and the amount of chlorine residual left after a certain length of time.

CHLORINE RESIDUAL: See residual. The amount of chlorine still left available after certain length of contact time.

CHOLERA: A severe, infectious, bacterial disease of the stomach and intestines, frequently epidemic and often fatal.

CLARIFIED: Settled; made clear.

CLEAR WELL: Reservoir for storing filtered water.

COLIFORM: A group of bacteria normally living in the intestines of man and animals and are also found elsewhere in nature. They are pollution indicators in water supplies.

COLLATION: To collect, compare carefully in order to verify, and often to arrange in proper order.

COLLOIDAL: Too finely divided to settle; Requiring coagulation, biochemical action, or membrane filtration for removal.

CONFORM: To give the same shape, outline, or contour to; to be obedient, especially to adapt to standards or customs.

CONGESTED: Clogged; causing too much fullness or concentration, as in a small or narrow space.

COMBINED CHLORINE RESIDUAL: The concentration of chlorine combined with ammonia as chloramine or as other chloro- derivitives, yet is still available to oxidize organic matter or carry on disinfection of water.

COMPACTED: Pressed tightly together.

COMPLEX: Complicated; having two or more parts.

COMPONENT: A unit of machinery. Also, a part of something.

COMPREHENSIVE: Covering completely or broadly.

CONE OF DEPRESSION: A cone-shaped hollow made in a water table as water is drawn from a well.

CONFIGUARATION: The shape or arrangement of parts in relation to each other.

CONSOLE: Panel or cabinet containing dials, switches, etc., used to monitor and control electric and mechanical equipment.

CONSTITUENT: An essential part; a component.

CONSUMER: A house, institution, store, industrial plant, or other users receiving water through a service pipe.

CONSUMPTION: The act or process of using up.

CONTACT BASIN: A basin used to put water or wastewater in contact with chemicals or other materials.

CONTAMINATION: The presence of microorganisms, chemicals, or wastes that make water unfit for use.

CONTINUITY: Uninterrupted connection, state, or activity.

CONTOURS: Outlines.

CONTRACTION: Narrowing section of a pipe or channel.

CONVENTIONAL: Traditional; the usual.

CORROSIVE: Having the power to eat or wear away by degrees.

CROSS REFERENCE: A notation or direction in one place (such as in a book or file) referring to information in another place.

DATA: Information from observations, measurements, and other facts.

DECOMPOSABLE: Able to undergo chemical breakdown, as in decaying.

DEFICIENCIES: Inadequacies; shortages; absences of quality or amount.

DEFICIENCY: The state of being without some necessary quality or element.

DENOTES: Indicates; makes known; means.

DETERIORATION: The state of having grown worse in quality.

DIATOMACEOUS: Earth made up mostly of the skeletal remains of diatoms.

DIATOMS: Single-celled microscopic algae that grow in or on water and have skeletons of silica.

DIFFERENTIATION: Distinction of difference in character; expression of a specific difference; discrimination.

DILUTION FACTOR: (Also called available dilution). The amount of water available to dilute a certain amount of water or wastewater.

DISINFECTION: Destruction of disease causing microorganisms by physical or chemical means (chlorination or boiling of water).

DISINTEGRATING: Breaking down or decomposing.

DISPERSED: Scattered and mixed.

DISSEMINATE: To spread widely.

DISTRIBUTION SYSTEM: A system of piping, canals, and associated equipment used to distribute a water supply to consumers.

DOLOMITE: A limestone rack rich in magnesium carbonate.

DRAWDOWN: A lowering of a water level in the ground pond or a tank.

DYSENTERY: A painful disease causing inflamed intestines and diarrhea with frequent discharges of blood and mucus. It is spread through unsanitary conditions surrounding food and water.

ENTERIC: Intestinal.

EXTRACTION: The act of withdrawing by physical or chemical process; pumping water from an acquifer.

FEASIBLE: Able to be done; reasonable or likely.

FILAMENT: A very long, thin cell or a series of very long, thin cells in various algae, fungi, etc. Also, a very fine thread; very slender threadlike part.

FILTER CAKE: Dewatered sludge or sediment.

FILTER MEDIA: The material through which water or wastewater is filtered.

FILTRATION: The process of passing a liquid through a filter to remove suspended solids.

FLOC: Small jelly-like masses formed in a liquid by adding a coagulant.

FLOCCULATION: The collection of coagulated suspended solids into a mass by gentle stirring.

FLOCCULATION AIDS: Materials added to liquid to form flocs.

FLOCCULATOR: Mechanical equipment used to encourage the formation of floc in liquid.

FLUME: Channel made of wood, masonry or metal on a grade and used to transport water.

GEOLOGICAL: Relating to the history of the earth, especially as recorded in rocks.

GLAND PACKING: Material used to aid in preventing leakage of fluid past a joint in machinery.

GPM: Abbreviation for Gallons per minute.

HEADLOSS: Reduction in the speed of flow through the filter.

HYDROLOGIC CYCLE: The movement of water from the atmosphere to the earth and back to the atmosphere through precipitation, infiltration, storage, transpiration, evaporation, etc.

HYDROLYSIS: A chemical process of decomposition using the addition of water. Also, the process solid matter goes through to become liquid.

IMMUNE: Protected; able to resist a particular disease.

IMPAIR: To make worse; injure.

IMPERVIOUS: Not allowing entrance or passage.

IMPINGE: To strike or hit sharply with force.

INCRUSTATION: A crust or hard coating.

INDICATOR BACTERIA: Coliforms that point to the presence of intestinal pathogens.

INFILTRATE: To pass into or through by filtering.

INFLUENT: Water or wastewater flowing into a treatment plant or any of its units.

INJECTION WELLS: Wells created to recharge groundwater.

INORGANIC: Made of matter that is not plant or animal.

INTENSITY: Degree of strength, force, or energy.

INTERDEPENDENCY: Depending on one another; the quality or state of being influenced by one another.

INTERMITTENT: Not continuous; happening or appearing with interruptions.

INTERNAL: Inside.

INTERPRET: To explain the meaning of; to understand in a particular way.

INTERRELATED: Sharing a relationship or connection.

INTERSECTING: Meeting and crossing.

IONEXCHANGE: A chemical process in which ions from two different molecules are exchanged.

IONIZING: Creating ions by adding electrons to, or removing them from atoms, or molecules.

IRON BACTERIA: Bacteria that use iron as food and discharge its compounds in their life processes.

IRRIGATION: The practice of supplying water to lands not receiving enough by rainfall.

JURISDICTION: The power, right, or authority to interpret and apply the law. Also, the limits or territory within which that authority may be used.

LATERALLY: A ditch or pipe entering or leaving a water main from the side.

LEACHING: Percolating liquid through soil or other solids to remove the soluble ingredients.

LOSS OF HEAD: Headloss.

METABOLIC: Having to do with the processes of building up food into living matter and using living matter until it is broken down into simpler substances or waste matter, giving off energy.

METABOLISM: The process in which food is used and wastes are formed by living matter.

METAL FATIGUE: The tendency of a metal to break under repeated stress.

MF: Membrane filter (used in bacterialogical lab test).

MGD: Millions of gallons per day.

MICRON: One millionth of a meter; micrometer.

MICROSCOPIC: Too small to see without using a microscope.

MINERAL: An inorganic substance (sand, metals, etc.).

MOTTLING: Marking with spots or blotches of different colour or shades of colour.

MPN: Most PROBABLE Number (used in bacterialogical lab test).

MUCOUS MEMBRANE: Skin that lines the body passages and cavities that open directly or indirectly to the outside.

NEGATIVELY CHARGED: Charged with electricity that has the electron for the elementary unit; charged so as to gain electrons; with lower electric potential.

OPTIMUM: The ideal, or most favourable condition.

ORGANIC: Made of matter that is plant or animal.

ORIFICE: A small opening through which water may flow.

OT TEST: Orthololidine test. A method of determining residual chlorine in water.

OVERBURDEN: The material lying over a deposit of useful geological materials.

OVERDRAFT: The state of being over drawn.

OZONIZATION: The act or process of charging or treating with ozone. Also, the conversion of oxygen into ozone.

PALATABLE: Agreeable or pleasant to taste.

PATHOGENIC: Disease producing bacteria.

PERMEABLE: Having pores or openings that permit liquids or gases to pass through.

POROSITY: The state of having pores; being permeable to liquids.

POSITIVELY CHARGED: Charged with electricity that has the proton as the elementary unit; charged to as to lose electrons; with higher electric potential.

POTABLE: Safe to drink; not polluted or contaminated.

PPB: Abreviatin for Parts per billion.

PRECAMBRIAN: Being the earliest era of geological history.

PRESSURE HEAD: A measure of the pressure exerted by a fluid.

PSEUDOMONAD: Short rod-shaped bacteria, some of which live on dead or decaying organic matter, or cause disease.

PSI: Abreviation for POUNDS per square inch.

PUMPING LEVEL: The height where water stands in a well during pumping.

QUANTITATIVE: Dealing with an amount.

RADIALLY: From the center towards the border.

REDUCING AGENT: A substance that causes the loss of an electron.

REHABILITATION: The act of restoring to usefulness.

REPLENISHED: Filled up again.

RESIDUAL: Remainder; something that is left, as in chlorine residual.

RETENTION TIME: Detention time; the length of time that water or wastewater is held in a unit for any treatment.

RPM: Abreviation for Revolutions per minute.

SAND FILTER: A filter using sand to remove suspended solids from water.

SATURATED: Full of moisture; made thoroughly wet.

SCORED: Marked with lines, grooves, scratches, or notches.

SEEPAGE: Liquid that flows or passes slowly through fine pores.

SEPTIC: Anaerobic (decomposition without oxygen).

SHALE: Rock formed of bonded layers of clay, mud, or silt.

SIGNIFICANCE: The quality of being important.

SOLUTION: A liquid containing a dissolved substance, or the condition of being dissolved. Also, the answer to a problem.

SOPHISTICATED: Highly complicated or developed.

SOURCE: The point where a distribution system or a collection system begins (origin of supply, place of origin).

SPORES: Walled, single to many celled reproductive bodies of microorganisms, able to preduce new organisms directly or indirectly.

STAINING: Colouring specimens for microscopic study. Also, colouring or discolouring anything.

STATIC LEVEL: The height of a water surface when ground water is not being removed.

STATISTICAL: Relating to the collection, analysis, interpretation, and presentation of great quantities of numerical facts.

STERILE: Without living organisms.

STRINGENT: Strict; severe.

SUBMERGED: Under water.

SUPERNATANT: The liquid standing above a sediment. In sludge digestion, the liquid standing between the sludge at the bottom and the scum at the top.

SURVEILLANCE: Supervision; close watch kept over something or someone.

SUSPENDED: Held up, as suspended solids in water.

SUSPENDED SOLIDS: Material which can be seen in water or wastewater and settled or filtered out.

SURFACE WATER: All water found on the surface of the earth.

TERMINATE: To bring to an end; to discontinue employment.

TITRATION: The method finding how much of something is in a solution by measuring how much of something else is needed to cause a chemical change.

TOXICANT: A toxic agent. Also, preducing a poisonous effect.

TRANSMISSIBILITY: The ability to transmit or percolate water.

TRANSMISSION: The act of sending or transferring something from one place to another.

TRANSPIRATION: The process by which plants return water to the atmosphere.

TURBULENCE: Disturbance, agitation. In water, irregular currents; not flowing smoothly.

VARIABLE: Able to change. Also, something changeable.

WATER HAMMER: Loud blows caused by moving water against the sides of its containing pipe.

WATERSHED: An area that drains into a particular body of water or water course.

WELL HEAD: The top of the well.

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